FOR THE INCREASE AND DIFFUSION OF KNOWLEDGE AMONG MEN

PER ORBEM

SMITHSONIAN INSTITUTION

WASHINGTON 1846

Annual Report of the Board of Regents

of the

SMITHSONIAN INSTITUTION

PUBLICATION 4613

Showing the Operations, Expenditures, and Condition of the Institution for the Year Ended June 30

1964

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LETTER OF TRANSMITTAL

SMITHSONIAN INSTITUTION,
Washington, January 28, 1965.

To the Congress of the United States:

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, on behalf of the Board of Regents, to submit to Congress the annual report of the operations, expenditures, and condition of the Smithsonian Institution for the year ended June 30, 1964.

Respectfully,

S. DILLON RIPLEY, *Secretary.*

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June 30, 1964

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Chancellor.—EARL WARREN, Chief Justice of the United States.
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ANTHONY J. CELEBREZZE, Secretary of Health, Education, and Welfare.

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Chief, supply division.—A. W. WILDING.
Chief, photographic service division.—O. H. GREESON.

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Registrar.—Helena M. Weiss.

MUSEUM OF NATURAL HISTORY

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Division of Ethnology: S. H. Riesenberg, curator; G. D. Gibson, E. I. Knez, W. H. Crocker, associate curators.
Division of Physical Anthropology: J. L. Angel, curator; Lucile E. Hoyme, associate curator.

DEPARTMENT OF ZOOLOGY: H. H. Hobbs, Jr., chairman; F. A. Chace, Jr., senior scientist; W. M. Perrygo, in charge of taxidermy.
Division of Mammals: D. H. Johnson, curator; H. W. Setzer, C. O. Handley, Jr., associate curators.
Division of Birds: P. S. Humphrey, curator; G. E. Watson, R. I. Zusi, associate curators.
Division of Reptiles and Amphibians: Doris M. Cochran, curator.
Division of Fishes: L. P. Schultz, curator; E. A. Lachner, W. R. Taylor, V. G. Springer, S. H. Weitzman, R. H. Gibbs, Jr., associate curators.
Division of Marine Invertebrates: D. F. Squires, curator; T. E. Bowman, C. E. Cutress, Jr., Marian H. Pettibone, R. B. Manning, D. L. Pawson, associate curators.
Division of Mollusks: H. A. Rehder, curator; J. P. E. Morrison, Joseph Rosewater, associate curators.

DEPARTMENT OF ENTOMOLOGY: J. F. G. Clarke, chairman.
Division of Neuropteroids: O. S. Flint, Jr., associate curator in charge.
Division of Lepidoptera: J. F. G. Clarke, acting curator; D. R. Davis, W. D. Duckworth, W. D. Field, associate curators.
Division of Coleoptera: O. L. Cartwright, curator; P. J. Spangler, associate curator.
Division of Hemiptera: R. C. Froeschner, associate curator in charge.
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Division of Phanerogams: L. B. Smith, curator; Velva E. Rudd, J. J. Wurdack, W. R. Ernst, D. H. Nicolson, S. G. Shetler, associate curators.
Division of Ferns: C. V. Morton, curator; D. B. Lellinger, associate curator.
Division of Grasses: J. R. Swallen, acting curator; T. R. Soderstrom, associate curator.

DEPARTMENT OF BOTANY—Continued

Division of Cryptogams: M. E. Hale, Jr., curator; P. S. Conger, H. E. Robinson, associate curators.

Division of Plant Anatomy: W. L. Stern, curator; R. H. Eyde, associate curator.

DEPARTMENT OF PALEOBIOLOGY: G. A. Cooper, chairman.

Division of Invertebrate Paleontology: R. S. Boardman, curator; P. M. Kier, Richard Cifelli, E. G. Kauffman, M. A. Buzas, R. H. Benson, associate curators.

Division of Vertebrate Paleontology: C. L. Gazin, curator; D. H. Dunkle, Nicholas Hotton III, C. E. Ray, associate curators.

Division of Paleobotany: F. M. Hueber, curator; W. H. Adey, associate curator.

DEPARTMENT OF MINERAL SCIENCES: G. S. Switzer, chairman.

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Division of Meteorites: E. P. Henderson, associate curator in charge; R. S. Clarke, Jr., chemist.

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MUSEUM OF HISTORY AND TECHNOLOGY

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Assistant Director.—J. C. Ewers.

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Division of Physical Sciences: R. P. Multhauf, curator; W. F. Cannon, Uta C. Merzbach, associate curators.

Division of Mechanical and Civil Engineering: S. A. Bedini, curator; E. A. Battison, R. M. Vogel, associate curators.

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Division of Ceramics and Glass: P. V. Gardner, curator; J. J. Miller II, associate curator.

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Division of Political History: W. E. Washburn, curator; Mrs. Margaret Brown Klapthor, K. E. Melder, Mrs. Anne W. Murray, associate curators; H. R. Collins, assistant curator.

Division of Cultural History: C. M. Watkins, curator; Mrs. Cynthia A. Hoover, J. N. Pearce, Rodris C. Roth, associate curators.

Department of Civil History—Continued

Division of Philately and Postal History: C. H. Scheele, associate curator in charge.

Division of Numismatics: Vladimir Clain-Stefanelli, curator; Mrs. Elvira Clain-Stefanelli, associate curator.

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Division of Military History: E. M. Howell, curator; C. R. Goins, Jr., associate curator.

Division of Naval History: P. K. Lundeberg, curator; M. H. Jackson, associate curator.

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Geochemists.—A. Long.

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Eugene M. Zuckert, Secretary of the Air Force.

Honorary Smithsonian Fellows, Collaborators, Associates, Custodians of Collections, and Honorary Curators

Office of the Secretary

John E. Graf

United States National Museum

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C. G. Holland, Archeology.

N. M. Judd, Archeology.

Betty J. Meggers, Archeology.

F. M. Setzler, Anthropology.

W. W. Taylor, Jr., Anthropology.

W. J. Tobin, Physical Anthropology.

Nathalie F. S. Woodbury, Archeology.

Zoology

O. L. Austin, Birds
W. W. Becklund, Helminthology.
J. Bruce Bredin, Biology.
W. L. Brown, Mammals.
Leonard Carmichael, Psychology and Animal Behavior.
Ailsa M. Clark, Marine Invertebrates.
H. G. Deignan, Birds.
Robert W. Ficken, Birds.
Herbert Friedmann, Birds.
Laurence Irving, Birds.
Allen McIntosh, Mollusks.
J. P. Moore, Marine Invertebrates.
Dioscoro S. Rabor, Birds.
W. L. Schmitt, Marine Invertebrates.
Benjamin Schwartz, Helminthology.
Robert Traub, Mammals.
Alexander Wetmore, Birds.
Mrs. Mildred S. Wilson, Copepod Crustacea.

Entomology

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M. A. Carriker, Jr.
C. J. Drake.
K. C. Emerson.
F. M. Hull.
W. L. Jellison.
C. F. W. Muesebeck.
T. E. Snyder.

Botany

C. R. Benjamin, Fungi.
E. C. Leonard, Phanerogams.
F. A. McClure, Grasses.
Mrs. Kittie F. Parker, Phanerogams.
J. A. Stevenson, Fungi.
W. N. Watkins, Woods.

Paleobiology

C. W. Cooke, Invertebrate Paleontology.
J. T. Dutro, Invertebrate Paleontology.
Remington Kellogg, Vertebrate Paleontology.
A. A. Olsson, Invertebrate Paleontology.
W. P. Woodring, Invertebrate Paleontology.

Mineral Sciences

Gunnar Kullerud, Mineralogy.
W. T. Schaller, Mineralogy.

MUSEUM OF HISTORY AND TECHNOLOGY

Science and Technology

D. J. Price

Civil History

Mrs. Arthur M. Greenwood, Cultural History.
E. C. Herber, History.
I. N. Hume, Cultural History.
F. W. McKay, Numismatics.
Mrs. R. Henry Norweb, Numismatics.
R. Henry Norweb, Numismatics.
Joan Jockwig Pearson, Cultural History.

Armed Forces History

W. R. Furlong.
F. C. Lane.
Byron McCandless.

Exhibits

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Bureau of American Ethnology

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Frank H. H. Roberts.
M. W. Stirling.
A. J. Waring, Jr.

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C. G. Abbot

Freer Gallery of Art

Oleg Grabar.
Grace Dunham Guest.
Max Loehr.
Katherine N. Rhoades.

National Air Museum

Frederick C. Crawford.
Alfred V. Verville.

National Zoological Park

E. P. Walker

Canal Zone Biological Area

C. C. Soper

Report of the Secretary of the Smithsonian Institution

S. DILLON RIPLEY

For the Year Ended June 30, 1964

To the Board of Regents of the Smithsonian Institution:

GENTLEMEN: I have the honor to submit a report showing the activities and condition of the Smithsonian Institution and its branches for the fiscal year ended June 30, 1964.

GENERAL STATEMENT

This past year, on January 31, marked the retirement of my predecessor, Dr. Leonard Carmichael, seventh Secretary of the Smithsonian Institution. In the Annual Report for 1963 there was presented a general review of the activities of the Institution from 1953 to 1963, which gives some impression of the magnitude of the changes and developments instituted under Dr. Carmichael's regime. This splendid administrator, who has done so much for the Smithsonian, deserves the very highest praise. Recognition of his accomplishments has been widely expressed, in honorary degrees conferred upon him and in decorations by foreign governments. The Institution will always be grateful to its seventh Secretary and proud of the record of progress and achievement that he helped to foster. Not the least have been the confidence and esteem which he developed with the Regents of the Institution, who have constantly supported and encouraged the programs of the Institution. The Smithsonian wishes Dr. Carmichael well in his new career as vice president for research of the National Geographic Society.

The Smithsonian and Higher Education

In the few months since the assumption of the post of Secretary by the present incumbent on February 1, 1964, certain proposals have been inaugurated with the support of the Regents. The general problem of the Smithsonian's role in cooperating with universities

and programs of higher learning has been explored. Such a program represents a continuation of the traditional role of the Institution in the educational field, although perhaps historically it received greater emphasis in the early days of the Smithsonian than it has in recent decades. The Smithsonian's first Secretary, Joseph Henry, said many years ago: "The Smithsonian, with its widening responsibilities among the arts as well as the sciences, must continue and expand its leadership in education and scholarship in America." It seems high time that we should develop this role, for there is urgent need for the Smithsonian to render genuine service and leadership.

In the broad areas of biology and anthropology, support for specialized training not otherwise available under existing university programs must and can be given by the Smithsonian. In addition to general programs in specialized fields, specific programs are currently being undertaken with eight universities. Duke University will cooperate with the Smithsonian Institution in training biological oceanographers. Johns Hopkins University will join in a common venture to offer graduate education opportunities in paleontology. Other programs of cooperative education have been developed with the University of Minnesota in algology, the University of Maryland in ornithology, George Washington University in malacology, and the University of Kansas in paleontology. In addition there is the well-known program of the Freer Gallery of Art and the University of Michigan in Oriental art and the Astrophysical Observatory's integrated activities with Harvard. Through such arrangements graduate students may come to the Smithsonian Institution to carry out research projects under the supervision of staff members who may be given recognition in the form of an honorary or part-time appointment to the university faculty. Improved use of museum and other laboratory facilities in this way will help to overcome severe national shortages of natural-science specialists in a number of fields.

As part not only of its service to the cause of higher education in this country but also in order to replicate specialists in careers of research and study associated with museum programs, the Institution must always stand ready to serve as a catalyst, to create opportunities for research for students and staff, and to foster interchange between scholars both here and abroad.

Cooperation with Museums

As a part of this wider usefulness of the Smithsonian to education, we hope that it may be possible to broaden the Smithsonian's traditional cooperation with museums throughout the world. Museums and their related laboratories are just entering a new era, and museum resources are being drawn upon as never before for general education.

Thirty years ago a mere 15 percent of museums in America were connected with education in some form. This marked a drastic decline from a hundred years ago when museums housed the genesis of scientific research in the Western World. Today over 90 percent are involved, ranging from simple school-extension programs to postgraduate fellowships. It is for these reasons that we feel that the Smithsonian, with its superb museum resources, now has a great opportunity to serve the museum world in a role of leadership and cooperation. As a first step in this effort, the Smithsonian Institution has entered into an agreement with the American Association of Museums to promote a joint publications program to facilitate the publication and distribution of works needed in the broad field of museum administration, education, museum services, and the science of museology.

Emphasis on Research

Research on wild populations and undisturbed conditions in nature has taken on an aspect of urgency in recent years because so many opportunities for study have changed or disappeared. But man's need to understand his environment and use it sympathetically will require a broad program of observation and research, especially in the tropics. The Smithsonian Institution will seek to promote interest in these objectives throughout the public and private scientific community. Beginning in April, Philip C. Ritterbush was appointed Special Assistant to the Secretary for Scientific Matters, to explore prospects for cooperation with other Government agencies in this effort and to promote consideration of these objectives in the development of national science policy.

A related objective is to strengthen the position, within science as a whole, of those fields of biology which have the entire organism as their object: ecology, genetics, systematics, botany, zoology, oceanography, microbiology, and paleontology, as well as the sciences of man which have so long been central concerns of the Smithsonian. Two related approaches to this subject have been begun. With hopes of contributing to the efficiency of research and investigation, studies are underway to promote the application of data processing, technician employment and training, improved cataloging methods, and more rapid means of indexing and retrieving information in the biological sciences. In order to overcome shortages of competent investigators, studies have begun to indicate appropriate means of expanding educational opportunity in neglected areas of the natural sciences.

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International Activities

During the period under review, the Institution made a determined effort to carry its international activities beyond traditional overseas field expeditions and research, which primarily benefit the Smithsonian, to cooperation with other Government agencies and private institutions in the development of exchange of persons and international exhibits programs, to the benefit of others.

Beginning in March, William W. Warner was engaged as a Consultant to the Secretary for International Activities to explore appropriate areas of international cooperation. The first of these has been in the field of archeology with the Department of State. The Department's Bureau of Educational and Cultural Affairs has expressed a strong interest in having the Smithsonian exercise a leading role in the administration of overseas archeological research or excavation projects in connection with those nations in which excess foreign currencies are available through agricultural surplus sales under Public Law 480. The Bureau has also welcomed the Institution's offer to help with the selection and programing of foreign scholarship candidates in fields of Smithsonian interest.

The Institution has also assisted the Department's Office of Soviet and Eastern European Exchanges in planning exchange of museum professionals and exhibits, in accordance with the new U.S.–U.S.S.R. Exchange Agreement, which for the first time includes specific mention of museums. The Secretary of the Smithsonian serves as chairman of the American Association of Museums' Soviet Exchange Committee, an advisory group that has helped the Department in the choice of museum professionals and possible exhibits going to and coming from Russia.

In addition, the Smithsonian has offered its storage facilities and staff assistance to the Department's "Art for Embassies," a project aimed at providing United States Embassies with representative American works of art. The first paintings lent under this project were turned over to the Smithsonian for safekeeping in June.

Among international organizations, the Smithsonian has supported the concept of American participation in the UNESCO campaign for the preservation of the monuments of Nubia in the upper Nile Valley. The Secretary has assisted the State Department in its request for a foreign currency appropriation to provide for American participation by explaining the significance of the monuments themselves and the interests of American universities and museums in the Nubian campaign in particular, and in the wider problems of classical archeology in the Near East in general.

During May the Organization of American States' Department of Scientific Affairs agreed to announce and fund, through its estab-

lished fellowship program, opportunities for Latin American students to serve as aides in research projects conducted at the Canal Zone Biological Area. Discussions have also been held on a jointly financed Organization of American States–Smithsonian program to provide postdoctoral research grants for Latin American scholars in environmental and descriptive biology tenable at both Barro Colorado in the Canal Zone and the Museum of Natural History.

The Institution has also discovered considerable interest among major American private foundations for cooperative programs in relatively neglected areas of basic science in the developing countries. The development of these and similar activities in future years can help fulfill the Institution's basic responsibility for the advancement of science and the humanities among all peoples.

THE ESTABLISHMENT

The Smithsonian Institution was created by act of Congress in 1846, in accordance with the terms of the will of James Smithson, of England, who in 1826 bequeathed his property to the United States of America "to found at Washington, under the name of the Smithsonian Institution, and establishment for the increase and diffusion of knowledge among men." In receiving the property and accepting the trust, Congress determined that the Federal Government was without authority to administer the trust directly, and, therefore, constituted an "establishment," whose statutory members are "the President, the Vice President, the Chief Justice, and the heads of the executive departments."

THE BOARD OF REGENTS

The Institution suffered a great loss this year in the death of Representative Clarence Cannon on May 12, 1964, the day before the spring meeting of the Board. Mr. Cannon had served as a Regent for nearly 30 years, longer than any other member of the Board. His wise counsel and unselfish devotion to the affairs of the Smithsonian will be sadly missed. On May 19 Representative George H. Mahon of Texas was appointed by the Speaker of the House of Representatives to fill this vacancy.

The roll of Regents at the close of the fiscal year was as follows: Chief Justice of the United States Earl Warren, Chancellor; members from the Senate: Clinton P. Anderson, J. William Fulbright, Leverett Saltonstall; members from the House of Representatives: Frank T. Bow, Michael J. Kirwan, George H. Mahon; citizen members: John Nicholas Brown, William A. M. Burden, Robert V. Fleming, Crawford H. Greenewalt, Caryl P. Haskins, Jerome C. Hunsaker.

On January 23, 1964, the annual meeting of the Board was held in the Regents' Room preceded by a private ceremony of installation of

the new Secretary. Dr. Leonard Carmichael, Secretary, presented his published annual report on the activities of the Institution. The Chairman of the Executive and Permanent Committees of the Board, Dr. Robert V. Fleming, gave the financial report for the fiscal year ended June 30, 1963.

On the evening preceding the annual meeting a formal dinner was held in the Hall of Graphic Arts of the Museum of History and Technology to celebrate the dedication of this new museum. The members of the Board and their wives as well as others directly concerned with the planning and construction of the new building were guests.

The spring meeting of the Board of Regents was held on May 13 in the Museum of History and Technology. The Chairman of the Executive Committee presented a financial report.

FINANCES

A statement of finances, dealing particularly with Smithsonian private funds, will be found in the report of the Executive Committee of the Board of Regents, page 274.

Funds appropriated to the Institution for its regular operations for the fiscal year ended June 30, 1964, totaled $13,191,000 and were obligated as follows:

Astrophysical Observatory	$994, 845
Bureau of American Ethnology	124, 228
Canal Zone Biological Area	138, 890
International Exchange Service	110, 000
National Air Museum	300, 075
National Armed Forces Museum Advisory Board	29, 115
National Collection of Fine Arts	143, 252
National Portrait Gallery	16, 678
United States National Museum	5, 587, 001
Office of the Secretary	257, 596
Buildings Management Department	3, 968, 759
Administrative Services	1, 464, 006
Unobligated	56, 555
	$13, 191, 000

Besides this direct appropriation, the Institution received funds by transfer from other Government agencies as follows: from the District of Columbia for the National Zoological Park, $1,597,356; from the National Park Service, Department of the Interior, for the River Basin Surveys, $254,500.

VISITORS

Visitors to the six Smithsonian buildings on the Mall again this year surpassed all records, with a total of 10,813,195, which was 503,359 more than for the preceding year. June 1964, with 1,592,540, was

the month of largest attendance; April 1964 second, with 1,555,295; and July 1963 third, with 1,407,858. The largest attendance recorded for a single day was 104,285 on March 28, 1964. Table 1 gives a summary of the attendance records for the six buildings. The National Zoological Park had an estimated 3,900,000 visitors during the year. When this figure is added to the attendance in the Institution's buildings on the Mall, and to the 1,236,155 recorded at the National Gallery of Art, the total Smithsonian attendance for fiscal 1964 aggregated 15,949,350.

SMITHSON BICENTENNIAL

The year 1965 marks the two-hundredth anniversary of the birth of James Smithson, founder of the Smithsonian Institution, and plans are in progress to observe this event in a manner that will draw international attention to Smithson and the work of the establishment he founded. A committee of Smithsonian staff members has been named, under the chairmanship of John C. Ewers, to plan the celebration and make recommendations to the Secretary concerning it. Scheduled for the fall of 1965, it is the intention to plan a program that will attract scholars and representatives of scholarly institutions and governments, from all parts of the world.

JOSEPH HENRY PAPERS

In collaboration with the National Publications Commission, the National Academy of Sciences, and the American Philosophical Society, a project has been initiated to collect, edit, and publish the Papers of Joseph Henry, first Secretary of the Smithsonian Institution. For at least a decade, scholars devoted to general American history as well as to the history of science in America have felt that such a documentary work would provide not only the story of this outstanding scientist but also much of the history of the organization of science in the United States, its relations with government, and its links with science and scientists in Europe. The significance of Henry was underlined in 1954 when the National Historical Publications Commission named him as one of the nonpolitical Americans whose papers are most worthy of publication.

Because of the enormity of the task and the high costs involved, it is impossible to say at this time how rapidly this project will move forward. Formation of a permanent committee to organize and direct the project is planned.

TABLE 1.—*Visitors to certain Smithsonian buildings during the year ended June 30, 1964*

Month and year	Smithsonian Building	Arts and Industries Building	Air and Space Building	Freer Gallery of Art	Natural History Building	Museum of History and Technology	Total
1963							
July	228, 648	518, 666	319, 413	22, 329	318, 802		1, 407, 858
August	212, 356	431, 120	350, 707	19, 409	316, 372		1, 330, 264
September	67, 003	139, 903	101, 234	12, 483	131, 354		451, 977
October	55, 765	141, 625	91, 332	10, 500	123, 116		422, 338
November	49, 513	101, 205	85, 122	9, 062	134, 430		379, 332
December	38, 720	76, 533	56, 726	7, 107	93, 325		272, 411
1964							
January	31, 741	61, 239	48, 553	6, 952	80, 872	132, 759	362, 116
February	39, 212	74, 072	59, 949	8, 572	116, 400	397, 751	695, 956
March	100, 597	168, 160	131, 962	13, 404	225, 691	397, 662	1, 037, 476
April	150, 659	277, 863	204, 217	20, 851	314, 030	587, 675	1, 555, 295
May	145, 228	213, 560	188, 100	15, 913	302, 547	440, 284	1, 305, 632
June	191, 619	252, 997	216, 871	22, 043	355, 367	553, 643	1, 592, 540
Total	1, 311, 061	2, 457, 243	1, 854, 186	168, 625	2, 512, 306	2, 509, 774	10, 813, 195

OPENING OF MUSEUM OF HISTORY AND TECHNOLOGY

On the evening of January 22, 1964, with a large and distinguished audience in attendance, dedication ceremonies were held for the formal opening of the new Museum of History and Technology. The program included music by the United States Marine Band, introductory remarks by Dr. Leonard Carmichael, Secretary of the Smithsonian Institution, who presided as master of ceremonies, and addresses by the Chancellor of the Smithsonian, the Honorable Earl Warren, Chief Justice of the United States; by the Honorable Clinton P. Anderson, United States Senator from New Mexico, Regent of the Smithsonian, and chairman of the Joint Congressional Committee on Construction of a Building for a Museum of History and Technology for the Smithsonian Institution; and by the President of the United States, Lyndon B. Johnson. The texts of these addresses were later printed in a brochure (Smithsonian Publication 4531) distributed by the Institution.

The history of the development and construction of this splendid new museum of the Smithsonian on Washington's Mall has been told in previous reports. Suffice it here to say that in many ways it has exceeded expectations in its acceptance and use by the public. From the day of opening until June 30, a period of 22 weeks, a total of more than 2,500,000 visitors entered its doors. At the time of opening about one-fifth of the total exhibition area of the building—50 halls—were ready for viewing.

LANGLEY MEDAL PRESENTATION

The Langley Medal of the Smithsonian Institution was awarded on May 5 to Astronaut Alan B. Shepard, Jr., in recognition of his "courageous and pioneering contributions to scientific research as the first American to fly in space and the first to control the attitude of a spacecraft while in flight and during a condition of weightlessness." Presentation, which coincided with the third anniversary of Shepard's historic flight, was made by Chief Justice Earl Warren, Chancellor of the Smithsonian, at a brief ceremony at the Institution. In attendance were members of the Smithsonian Board of Regents, including Senator Clinton P. Anderson, who made a brief address; officials of the National Aeronautics and Space Administration; Smithsonian officials; and members of Commander Shepard's family. This was the eleventh time the Smithsonian Institution had awarded the Langley Medal in the 56 years since its establishment in 1908.

LECTURES

Elmer A. Sperry, Jr., eminent inventor, delivered the fifth Lester D. Gardner lecture, "Early Airplane Instruments," in the auditorium of the Freer Gallery of Art on the evening of September 27.

Dr. James A. Van Allen, professor of physics, University of Iowa, gave the 29th Annual James Arthur Lecture on the Sun on the evening of December 12, 1963, in the auditorium of the Natural History Building. His subject was "Some General Aspects of the Earth's Radiation Belts."

Ben Norris, painter and professor of art, University of Hawaii, delivered an illustrated lecture, "Images from Hawaii—From Captain Cook to Contemporary Crossroads," on January 20, 1964, in the auditorium of the Natural History Building. This lecture was sponsored by the Hawaii State Society of Washington, D.C.

George Bass, special assistant for underwater archeology, University of Pennsylvania University Museum, lectured on "Diving 3,000 Years into the Past" in the auditorium of the Natural History Building on the evening of January 24, 1964. This illustrated lecture was sponsored jointly by the Smithsonian Institution and the Archaeological Institute of America.

The Honorable Desmond Guinness, president of the Irish Georgian Society, gave an illustrated lecture on "18th Century Georgian Architecture in Ireland" in the auditorium of the Natural History Building on the evening of February 8, 1964.

The first Edwin A. Link Lecture, "Training by Simulation," was delivered by Astronaut Alan B. Shepard, Jr., in the auditorium of the Natural History Building on the evening of February 19, 1964. This series of lectures, made possible by a grant from the Link Foundation, is administered by the Smithsonian Institution in cooperation with the U.S. Office of Education.

Miss Sylvia Kenney, associate professor of music at Bryn Mawr College and visiting associate professor of music at Yale University, gave a lecture on the subject "Paintings, Chronicles, and Stylistic Criteria as Guides for the Performance of 15th Century Music" in the auditorium of the Natural History Building on the evening of May 22, 1964.

Several lectures sponsored by the Freer Gallery of Art and the National Gallery of Art are listed in the reports of these bureaus.

THE KENNEDY CENTER

In January the National Cultural Center, a bureau of the Smithsonian Institution, by act of Congress was renamed the John F. Kennedy Center for the Performing Arts as a memorial to our late President. By this same act, appropriation of $15.5 million was authorized

from Federal funds to match contributions from the public. Under the chairmanship of Roger L. Stevens, the Center made notable progress during the year toward its objectives. Many substantial gifts were received. Questions relating to the size and site of the Center have been resolved, and plans call for construction of the substructure to begin in the summer of 1965. It is estimated that about 2½ years will be required to complete the building. The Secretary of the Smithsonian Institution serves ex officio as a member of the board of trustees of the Center. Also serving on the board are Senator Leverett Saltonstall and Senator J. William Fullbright, both Regents of the Institution. A detailed report on the John F. Kennedy Center for the year, together with a financial statement, is presented beginning on page 247.

NATIONAL ARMED FORCES MUSEUM ADVISORY BOARD

During the year the National Armed Forces Museum Advisory Board gained a staff to provide assistance in the execution of its missions as assigned by Public Law 87–186. The staff head, designated Coordinator of Studies, is Col. John H. Magruder, III, U.S. Marine Corps. Colonel Magruder, Director, Marine Corps Museums, was detailed by the Secretary of the Navy to work part-time with the Board. He reported for duty October 2, 1963. Other staff members are James S. Hutchins, Assistant Coordinator of Studies (reported December 2, 1963); Col. Robert M. Calland, U.S. Marine Corps, Retired, Museum Specialist (reported June 1, 1964); and Mrs. Miriam H. Schuman, Administrative Assistant (reported September 23, 1963).

The Board, at its third meeting, January 20, 1964, unanimously endorsed Fort Washington, Md., now administered by the National Park Service, as the most feasible and appropriate site for the proposed National Armed Forces Museum. The Board also recommended to the Smithsonian Board of Regents that necessary arrangements be made with the National Park Service and the Congress to provide for the transfer of that site to the Smithsonian Institution.

Accordingly, representatives of the Smithsonian Institution opened negotiations with the National Park Service looking to acquisition of Fort Washington. On March 16, 1964, the Secretary met with T. Sutton Jett, Director of the National Capital Region, National Park Service, and discussed with him the Board's interest in obtaining the Fort Washington site. On May 14, 1964, the subject again was discussed at a meeting between the Secretary and George B. Hartzog, Director of the National Park Service. Further negotiations with the Park Service are in progress.

During the year the staff of the National Armed Forces Museum Advisory Board opened negotiations with various agencies of the Armed Forces and the General Services Administration in regard to

the retention and eventual transfer to the Smithsonian Institution of military and naval objects appropriate for the collections of the National Armed Forces Museum. In addition, the staff undertook its own thorough search for such objects at military and naval installations throughout the continental United States. The staff, in cooperation with the Smithsonian Library, also initiated steps to acquire from Armed Forces historical agencies and elsewhere significant publications in the fields of military and naval history, to serve as a nucleus of the study center library of the proposed museum. All governmental agencies are cooperating fully with the work of the Board. Once a site for the museum has been fixed, there will be no dearth of materiel around which to establish a museum exhibit plan.

SCIENCE INFORMATION EXCHANGE

The Science Information Exchange (S.I.E.) receives, organizes, and disseminates information about scientific research in progress. Its mission is to assist the planning and management of research activities supported by Government and non-Government agencies and institutions by promoting the exchange of information that concerns subject matter, distribution, level of effort, and other data pertaining to current research in the prepublication stage. It helps program directors and administrators to avoid unwarranted duplication and to determine the most advantageous distribution of research funds. It serves the entire scientific community by informing individual investigators about who is currently working on problems in their special fields.

The Exchange is concerned only with research actually in progress in order to cover the 1- to 3-year information gap between the time a research project is proposed or started and the time the results become generally available in published form. Thus, the Exchange complements, rather than duplicates, the services of technical libraries and established documentation centers.

Information is received by the Exchange from all available sources, specifying who supports a research task, who does it, where it is being done, and a 200-word technical summary of what is being done. These basic data are cast into a one-page record, the Notice of Research Project (N.R.P.) that serves as the major input and output of the Exchange. These records are analyzed, indexed, processed, and stored in computer and manual files in such a way that a wide variety of questions about any of these items or any combination of items can be quickly retrieved or compiled.

The acquisition of task records and the input workloads have continued to climb rapidly, from about 56,000 in fiscal year 1962 to 75,000 in 1963 and over 100,000 in 1964. The output services rendered to United States Government agencies and for the entire scientific

community have also increased rapidly, from about 27,000 reports of all kinds in 1963 to about 34,000 this fiscal year. Over three-quarters of a million research task records (N.R.P.'s) were requested and dispatched during the year.

With the rapidly increasing demands, the total staff, including about 40 scientists, grew to 155, but in recent months it has dropped slightly, reflecting in part the economies resulting from improved organization and systems control.

To handle this rapidly increasing volume of records more efficiently and economically, the reorganization and expansion of the Exchange were completed during the past year. An entirely new assembly line system now is capable of receiving and processing well over 100,000 records per year. The system is easily controlled and is amenable to expansion or contraction as workloads may dictate. Each unit process, each organizational unit, and each of the different kinds of services rendered can be identified and the unit costs can be determined by a new accounting system developed and put into operation in recent months.

For almost 15 years, the Exchange was supported by a number of Federal agencies whose far-sighted research directors and administrators were aware of the fact that the management of multimillion-dollar research programs might well be facilitated by the prompt exchange of information about on-going programs. As this enterprise grew rapidly in recent years, support and management problems became more complex and difficult for individual agencies, and so, in 1964, the National Science Foundation undertook the responsibility for funding and overall management with continued operational responsibility under the aegis of the Smithsonian Institution.

It is axiomatic that maximum use should be made of the large number of research records acquired, processed, and stored by the Exchange. To this end, S.I.E. has endeavored to make these services known and available to all eligible users. During the past year, five articles were published in professional journals by staff members describing S.I.E. and its services. Twenty-three articles and news notes about S.I.E. were published by others. Over 25,000 descriptive brochures were requested and distributed. About 685 visitors, including a number from overseas, called at the Exchange to find out how these stores of information could be adapted to their own scientific information and research management problems. S.I.E. staff presented 26 talks, papers, and briefings to professional scientific societies, groups, and organization units. All these activities indicate a growing interest in S.I.E. throughout the scientific community, and there is good reason to believe that these activities are the most effective ways of increasing the use of S.I.E. and thereby contributing to effective management of research projects and programs.

By the end of this year all Federal agencies with significant research programs were participating in some degree in the S.I.E. program. About 90–95 percent of all Government research in life sciences and social sciences is being registered. In general, the physical sciences collection has grown slowly, but some fields now are approaching fairly comprehensive proportions. An estimated 15,000 to 20,000 records dealing mostly with applied research in physical sciences are still to be registered. Interest among non-Government agencies, universities, foundations, national fund-raising agencies, industry, State and city research agencies, has been growing substantially even though S.I.E. has concentrated its efforts in the past on Federal agency participation. Closer cooperation with non-Government agencies may be anticipated as the Federal collections approach comprehensive proportions.

To determine if S.I.E. does, in fact, fulfill its mission and effectively achieve its objectives, a questionnaire was sent to 600 scientists who have used the Exchange services. From their response, it was evident that over 95 percent received information concerning new research they did not know about, even in their own specialty fields. The majority used the information to keep up with latest developments and to avoid duplication in formulating new projects and research proposals. Over 70 percent affirmed good scientific quality, comprehensive coverage, and no irrelevant material. Over 60 percent indicated their interest and endorsement by volunteering comments and suggestions. Although the purpose of the questionnaire was primarily as guidance for S.I.E., this practical field test of an actual operating system and its products seems to offer objective and concrete evidence that this kind of information service on current research is needed and is acceptable to the research scientists for whom it was designed.

SMITHSONIAN MUSEUM SERVICE

The Smithsonian Museum Service, through appropriate educational media, interprets to museum visitors and to the general public the objects, specimens, and exhibits in the several Smithsonian museums and develops interpretative and educational programs relating to the work of the Institution in the fields of science, history, and art. The Museum Service also cooperates with the volunteers of the Junior League of Washington, D.C., who conduct the Junior League Guided Tour Program at the Smithsonian. A more complete report of this activity, directed by G. Carroll Lindsay, curator, with the assistance of Mrs. Nella Lloyd, visitor services assistant, is carried in the report on the U.S. National Museum (pp. 65–66).

In addition, the Museum Service acts to coordinate special events and ceremonial activities involving the Smithsonian museums and outside organizations.

The Museum Service provided assistance to professional groups and individuals visiting the museums of the Institution or planning to do so. Assistance in the form of lectures, answers to inquiries, and special tours of museum areas was rendered to college and university groups and individuals from the United States and abroad. Mr. Lindsay served as consultant on museum organization and practices to representatives from other museums on several occasions.

The Audioguide, or radio lecture system, in the Museum of Natural History continued in operation and was used by 39,504 persons. The complete text of the 37 Audioguide lectures was published during the year under the title *The Exhibits Speak.* In the Museum of History and Technology tape-recorded lectures describing the exhibits were made available to visitors to the First Ladies Hall. This system, using self-contained, battery-powered tape playback machines, is known as Acoustiguide.

Assistant curator Mrs. Sophy Burnham wrote, produced, and directed a 27-minute, 16-millimeter, color motion picture, *The Leaf Thieves.* The film shows research activities, field work, and exhibition preparation carried on by the Museum of Natural History, and included footage exposed in British Guiana during the 1962 Smithsonian Botany-Exhibits Expedition to that area. It is designed to acquaint students with the opportunities for scientific or technical careers in natural history museums.

The film *The Smithsonian's Whale*, describing the construction of the 92-foot model of a blue whale on exhibit in the Museum of Natural History, was distributed from 10 points across the United States and was shown on television stations in Washington and New York. Prints of this film also were borrowed directly from the Museum Service. This film was selected from films produced by Government agencies for showing at the Venice Film Festival in Venice, Italy.

The staff docent in zoology, Mrs. Linda Gordon, and the staff docent in anthropology, Mrs. Marjorie Halpin, continued to handle non-technical correspondence from the public on their respective subjects; they provided tours for groups visiting the museum; lectured before classes visiting the museum; and prepared information leaflets on exhibition halls, bibliographies, and similar educational materials.

Special "touch" tours for several groups of blind persons were arranged during the year. Specimens and objects from the reference collections as well as selected portions of the public exhibits were included in the programs arranged for the blind.

The Urban Service Corps program, under the general direction of Mrs. William Wirtz, held seven sessions at the Smithsonian. Emphasis was placed on the work of the Musuem of Natural History, and the programs, designed to stimulate student participation, included lectures and tours of its exhibit areas and technical laboratories. At the

conclusion of one of the regularly scheduled Urban Service Corps programs, a special session was devoted to the Museum of History and Technology (at that time not yet open to the public). Scientific and administrative staff members of the Institution also participated in these programs.

Miss Mary Ann Friend continued her work as audiovisual librarian, cataloging slides and arranging for the loan of slides, films, and photographs related to Smithsonian exhibits and research activities. Facilities of this library were extensively used by Smithsonian staff members and by borrowers outside the Institution.

During the year the responsibility for operating the museum sales shops was transferred to the Museum Service, and Mrs. Emily Pettinos, formerly with the University Museum, University of Pennsylvania, joined the staff as manager of the sales operations. The shops serve as an adjunct to the educational program of the Institution, making available to the visitors printed materials relating to the work of the Institution and reproductions of materials in the museum collections. Three shops are operated in the Museum of History and Technology and one each in the Museum of Natural History and the Arts and Industries Building.

Arrangements were made by the Museum Service for various Smithsonian public functions and special events, including the opening of new exhibit halls, temporary exhibitions, film showings, lectures, visitations by heads of state and other distinguished visitors, and the opening of the Museum of History and Technology. More complete information about these activities will be found under appropriate headings elsewhere in this report. Current mailing lists for announcements of these events were maintained.

The *Smithsonian Calendar of Events*, a listing of special events held at the Institution, was prepared and distributed monthly. An illustrated directory to museums in the Washington metropolitan area was prepared by the Museum Service and published by the Institution, under the title *Brief Guide to the Museums in the Washington Area.*

The Museum Service continued to assist radio and television producers wishing to feature Smithsonian exhibits and scientific work in local or network programs. In this regard the Museum Service acts as liaison between the broadcaster's representatives and the various operating units of the Institution.

William C. Grayson, formerly with the National Broadcasting Co., joined the staff as consultant to assist in the preparation of plans for more effective Smithsonian participation in various aspects of television and radio activity, including the use of the television studio in the Museum of History and Technology.

Meredith Johnson, formerly director of Woodlawn Plantation, joined the staff of the Museum Service to assist in the development of

educational and visitor service programs, particularly in regard to the greatly increased demands for such services arising upon the opening of the Museum of History and Technology.

During the year curator G. Carroll Lindsay attended various professional meetings and conferences. He appeared on the programs of the following meetings: The Annual Winterthur Seminar on Museum Operation and Connoisseurship, Winterthur, Del.; the Museum Audio-Visual Applications Group, Rochester, N.Y.; the American Association of Museums Annual Meeting, St. Louis, Mo. He also attended the annual meetings of the Division of Audio-Visual Instruction, National Education Association, Rochester, N.Y.; and the Museum Stores Association, Chicago, Ill.

He also lectured before various groups visiting the Institution, describing for them the history and current work of the Smithsonian, and presented similar talks before meetings of local service clubs and other groups interested in the Institution.

Mr. Lindsay continued his research in the field of early American culture. He also presented lectures to the St. Mary's County, Md., Historical Society and to the National Trust Conference for Historic Museum Associates on the subject of southern colonial architecture; participated in the annual Forum held by the Alexandria (Va.) Association and spoke on early Alexandria architecture; presented a series of four lectures on early American furniture as part of the Junior League of Washington's adult education program; and lectured at the Cheltenham Township (Pa.) Adult School on the subject of early American silver. He appeared four times on television programs to discuss the work of the Smithsonian Institution and twice for the same purpose on radio programs.

The curator and the consultant on TV installations, William C. Grayson, traveled to New York to consult with the program director of Lincoln Center. They also observed the visitor information facilities in Williamsburg, Va.

The assistant curator attended the Calvin Motion Picture Studio Workshop seminar on motion-picture production in Kansas City, Mo.

The audiovisual librarian, Miss Mary Ann Friend, represented the Museum Service at the American Film Festival of the Educational Film Library Association in New York City for the entry of one of our films.

The museum docents have made trips to the American Museum of Natural History to examine the education programs and confer with staff members. In addition, the docent in zoology traveled to Boston to examine the education department at the Science Museum. The docent in zoology attended the International Congress on Zoology which consisted of seminars and a film theater in action.

Report on the United States National Museum

SIR: I have the honor to submit the following report on the condition and operations of the U.S. National Museum for the fiscal year ended June 30, 1964:

COLLECTIONS

During the year, 1,234,752 specimens were added to the national collections and distributed among the 10 departments as follows: Anthropology, 38,484; zoology, 196,427; botany, 30,427; entomology, 241,947; mineral sciences, 9,186; paleobiology, 376,007; science and technology, 1,361; arts and manufactures, 2,697; civil history, 336,393; and Armed Forces history, 1,823. This year's accessions were acquired as gifts from individuals, by staff collecting in the field, or as transfers from Government departments and agencies. The complete report on the Museum, published as a separate document, includes a detailed list of the year's acquisitions, of which the more important are summarized below. Catalog entries in all departments now total 58,755,099.

Anthropology.—Two large and important North American collections were accessioned in the division of archeology. One, received by transfer from the River Basin Surveys, Bureau of American Ethnology, included 18,603 specimens from the Medicine Creek Reservoir, Nebraska, and comprises one of the largest and most complete collections extant on the prehistoric agricultural peoples of the Central Plains in the 9th to 14th centuries. The second lot is from the 1931–32 investigations of the Bureau of American Ethnology at Signal Butte, a key stratified site in western Nebraska with a series of occupational levels spanning the period from 2600 B.C. to about A.D. 1700. Other noteworthy accessions include 6,031 pieces collected by the Bureau of American Ethnology from the Parita and Santa Marta areas in Panama; a group of handaxes from the Fezan and microlithic blades from Tripolitania, Libya, presented by James R. Jones of the U.S. AID mission to Libya; and an exceptionally well-preserved Egyptian cat mummy donated by Edith Goldsmith of Methuen, Mass.

In the division of ethnology, a large portion of the year's acquisitions were obtained, chiefly by purchase, for use in the new Hall of Cultures of Africa and Asia. Noteworthy Asian accessions included:

79 specimens representing Chinese opera, purchased with aid of the Chinese National Government; 116 items relating to agriculture and daily life in Japan, obtained from the Japanese Association of Museums; a Hindu village altar assemblage of 40 specimens, purchased with assistance of the Government of Orissa, Bhubanaswar, and the Crafts Museum, New Delhi; 255 Burmese items purchased from the collector, Brian Peacock, University of Rangoon; 226 specimens mostly from Isfahan and dealing with Iran textile printing, collected and donated by Mrs. Ethel J. W. Bunting; 76 items of Korean furniture, architectural pieces, and objects of everyday use, presented by the Korean Ministry of Public Information; 5 traditional Japanese swords, with scabbards and a leather sword case, presented by Adm. William M. Fechteler; a ceremonial bone apron from Tibet, by exchange from Simon Kriger, Washington, D.C.; and 3 large rubbings of stone relief from the Bayon at Angkor, donated by the Kingdom of Cambodia. To the African collections were added 60 items from the Endo-Marakwet of Kenya, purchased for the Museum by Deric O'Bryan, formerly U.S. Foreign Service Officer in Nairobi; and full-scale copies of six rock paintings from the Tassili Mountains of Algeria, made at the Musée de l'Homme under direction of Henri Lhote.

Among the accessions in the division of physical anthropology are two casts of trephined skulls from Peru, one with five and the other with seven openings; these will be exhibited as examples of the number of trephine openings which have been made in a skull in vivo. Two Kraho Indian face masks from central Brazil were made for the Museum by Harold Schultz. One is to be incorporated in the map of peoples of the world in the new hall of physical anthropology in preparation. Other accessions include skeletal materials from Virginia, Maryland, Latin America, and Alaska.

Zoology.—A currently accelerated program of field activities in the division of mammals added 14,869 specimens to its collections. Field parties working under the direction of Dr. Henry W. Setzer collected more than 5,000 specimens from Africa and southwestern Asia. The tropical areas of the Americas continued to provide large numbers of specimens. Of special note are Dr. C. O. Handley's general collections from Panama and Arthur M. Greenhall's large collection of bats from Trinidad. Important accessions also include a rare marbled cat from Sumatra presented by Kent Crane, a series of baboons obtained by Clifford E. Sanders in Northern Rhodesia, South American marmosets received from the National Institutes of Health Primate Colony at the San Diego Zoo through Robert W. Cooper, and a good series of canids allied to red wolves from the south-central part of the United States received through the Fish and Wildlife Service.

Accessions worthy of special note received in the division of birds

include 547 bird skins, 26 skeletons, 1 egg, and 1 nest from Panama, received through Dr. Alexander Wetmore; 791 bird skins, 85 skeletons, and 1 nest from North America, by transfer from the Fish and Wildlife Service; 301 bird skins from Formosa, by transfer from the Department of Defense, Department of the Navy, U.S. Naval Medical Research Unit No. 2, through Dr. R. E. Kuntz; 190 bird skins from North Borneo, gift of the Bernice P. Bishop Museum through Dr. J. L. Gressitt; 175 bird skins from West Pakistan, gift from Bucknell University through Dr. Roy C. Tasker; 156 alcoholic specimens of birds from Prof. D. S. Rabor, Silliman University, Dumaguete City, Negros Oriental, Philippines; and 52 original watercolor paintings executed as illustrations for F. Salomonson's "The Birds of Greenland" by deposit from the artist, Aage Gitz-Johansen, Trorod, Denmark, through Dr. Carl Christensen, Cultural Counselor, Embassy of Denmark.

The division of reptiles and amphibians accessioned 2,639 specimens. Outstanding among these are 58 West Indian lizards and frogs, including paratypes of 13 new species and subspecies from Dr. Albert Schwartz of Miami, Fla.; 213 reptiles and amphibians from Madagascar collected by field parties under the direction of Dr. H. W. Setzer of the division of mammals; and 219 reptiles and amphibians from Darién, Panama, collected by Dr. Charles O. Handley, Jr., also of the division of mammals.

Among the largest accessions made in the division of fishes during the year were 5,777 specimens received by transfer from the U.S. Fish and Wildlife Service, mostly through the efforts of Dr. Daniel Cohen, Harvey R. Bullis, Jr., Willis King, J. H. Finucane, and P. J. Struhsaker; a gift of 3,000 specimens of Panamanian fishes from Horace Loftin, Florida State University; and through exchange, 6,020 Virginia fishes from Dr. Robert Ross, Virginia Polytechnic Institute. Dr. Herbert R. Axelrod, T. F. H. Publications, Inc., Jersey City, N.J., donated 443 South American fishes and aided in securing 18 additional ones. Especially important acquisitions are holotypic and paratypic specimens received from Dr. Jacques R. Géry, Dordogne, France; Dr. Edward C. Raney, Cornell University; Dr. John E. Randall, University of Puerto Rico; Dr. Eugenia Clark, Cape Haze Marine Laboratory; Wayne J. Baldwin, University of California; Dr. C. Lindsey, University of British Columbia; Dr. J. L. B. Smith, Rhodes University, Grahamstown, South Africa; and Dr. Stanley Weitzman, associate curator in the division of fishes. The addition of 47 shark specimens, some undescribed and others representing species not previously contained in the national collections, was made by the following: Dr. J. C. Briggs, University of Texas; H. Heyamoto and Susumu Kato, U.S. Fish and Wildlife Service; Donald Goff, Rehoboth Beach,

Del.; Dr. Carl L. Hubbs, Scripps Institution of Oceanography; Dr. T. Abe, University of Tokyo, Japan; Dr. F. H. Talbot, South African Museum; and Jeanette D. D'Aubrey, Oceanographic Research Institute, Durban, Natal, South Africa. Valuable specimens were also received from Mac Entel, Sumac Tropical Fish Hatchery, Miami, Fla.

The addition of 27,003 Antarctic specimens to the division of marine invertebrates, collected by Dr. Waldo L. Schmitt, was of special importance. Dr. Schmitt, research associate of the division, participated in the U.S. Antarctic Research Program aboard the USS *Staten Island* and made these collections during the Palmer Peninsula-South Shetlands Survey in 1963. Many existing gaps in the national collections of the fauna of these regions have now been filled. Acquisition of the A. Weir Bell collection of Oligochaeta, comprising about 900 slides of sections of these worms, a catalog, and a library of separates of scientific articles dealing with the oligochaetes, was a significant event during the year. This important collection was obtained from Dr. R. A. Boolootian, Department of Zoology, University of California, Los Angeles. A collection of 2,216 specimens of polychaete worms from the Bering Sea was received from Dr. Donald J. Reish, Long Beach State College, Long Beach, Calif.

In the division of mollusks, 69,288 specimens were added during the year, including 334 specimens from previously recorded accessions, the largest annual increment since 1953–54. This large increase is due mainly to three large accessions: The personal collection of Arnon L. Mehring consisting of approximately 23,800 specimens; a collection of 17,300 specimens mainly from Okinawa, Ryukyus, purchased through the Chamberlain Fund; and 7,600 specimens gathered by Dr. Harold A. Rehder in Tahiti utilizing funds provided by Gen. Frank R. Schwengel in memory of his wife, Jeanne S. Schwengel. Other large accessions include an exchange with the Academy of Natural Sciences of Philadelphia of 1,350 specimens, and a gift of 1,480 specimens from Duncan Emrich of Washington, D.C. Holotypes were received from the Institute of Marine Science, University of Miami, through Dr. F. M. Bayer; the U.S. Fish and Wildlife Service Laboratory, Pascagoula, Miss., through Harvey R. Bullis, Jr.; and from Richard E. Petit. A total of 843 specimens including a number of holotypes were added to the helminthological collection during the year. The largest accession, consisting of 339 lots collected in Panama in 1931–34, was presented by Dr. A. O. Foster.

Entomology.—The division of Coleoptera received a total of 49,528 specimens in 66 accessions. Major contributions include the following: 730 beetles from Nepal and Pakistan from Dr. J. Maldonado Capriles, University of Puerto Rico; 1,000 North American ground beetles from John D. Glaser, Baltimore, Md.; 5,500 beetles from Cen-

tral America and the United States from Dr. John Kingsolver, Insect Identification and Parasite Introduction Research Branch, U.S. Department of Agriculture; and 1,100 Mexican beetles from Dr. Alfred B. Lau, Mexican Indian Training Center, Cordoba, Vera Cruz, Mexico.

As a result of field work conducted by members of the Smithsonian staff the following were acquired: 1,100 miscellaneous South American beetles from Mrs. Doris H. Blake and Dr. Doris M. Cochran; 300 scarab beetles from South Carolina obtained by O. L. Cartwright; and 35,600 miscellaneous Mexican and North American beetles collected by Dr. Paul J. Spangler.

The division of Hemiptera received 81,757 specimens in 100 accessions during the year. The most important acquisition of the year was the J. Douglas Hood collection of Thysanoptera (thrips), which contains 1,055 holotypes and 11,203 paratypes of Hood and other workers. The transfer of the very important collection of North American fleas from the Rocky Mountain Laboratory of the National Institute of Allergy and Infectious Diseases, Department of Health, Education, and Welfare, was initiated through the efforts of Dr. William L. Jellison, retired, of that Institute. To date 12,780 carefully prepared slides from this collection have been received. The Scripps Institution of Oceanography, through the cooperation of Dr. Martin W. Johnson and H. George Snyder, presented over 1,300 specimens of the marine water-strider genus *Halobates*. Other important accessions are: 1,144 ants from the Nevada Atomic Test Site through the cooperation of Dr. Donald M. Allred, Atomic Energy Commission; 500 Australian ants from Prof. B. B. Lowery, St. Ignatius College, Sydney, Australia; and 215 South American ants from Dr. K. W. Cooper, Hanover, N.H. Other Hymenoptera, 130 named European wasps from W. S. Pulawski, University of Wroclawskiego, Warsaw, Poland; 486 North American wasps from Dr. K. V. Krombein, Arlington, Va.; 157 South American velvet ants from Dr. Osvaldo H. Casal, Instituto Nacional de Microbiología, Buenos Aires, Argentina; 443 Old World cercerid wasps from Dr. H. A. Scullen, Oregon State University, Corvallis, Oreg.; 450 North American and Russian chalcid-flies from C. D. F. Miller, Canadian Department of Agriculture, Ottawa, Canada; and 100 European chalcid-flies from Dr. A. Hoffer, Prague, Czechoslovakia.

The division of Lepidoptera[1] received 72,324 specimens as the result of field activity of staff members and cooperating agencies. Significant contributions made by staff members include 9,115 Mexican moths collected by Drs. Don R. Davis and W. Donald Duckworth; 1,280 butterflies from eastern United States collected by William D.

[1] See footnote on page 66.

Field; and 5,746 Lepidoptera (including 760 reared specimens) and 155 Diptera from the Island of Rapa, contributed by Dr. and Mrs. J. F. Gates Clarke. Dr. William L. Stern, Department of Botany, presented 134 Philippine butterflies and moths; C. W. Sabrosky, U.S. Department of Agriculture, contributed 297 North American flies; 2,718 North American flies were received from Dr. C. P. Alexander of Amherst, Mass.; 92 Asian flies, including 1 holotype and 9 paratypes, came from Dr. Edward L. Coher of Waltham, Mass.; Dr. D. Elmo Hardy, Honolulu, presented 146 South American flies, including 4 holotypes and 2 allotypes; and 103 Japanese moths were received from Dr. H. Kuroko of Fukuoka Prefecture, Japan. By transfer, 45,004 specimens, including all groups of insects, were received from the Insect Identification and Parasite Introduction Branch, U.S. Department of Agriculture.

The division of Myriapoda and Arachnida received some extremely valuable material totaling 4,369 specimens in 32 transactions. H. F. Loomis continued to enrich our millipede collection with approximately 300 Neotropical specimens, both typical and ordinary; Dr. G. E. Ball, University of Alberta, Edmonton, Alberta, presented 425 centipedes from Canada, southwestern United States, and Mexico. Dr. R. L. Hoffman, Radford College, Blacksburg, Va., sent 160 centipedes and millipedes, including types of the latter from the United States; Curator Ralph Crabill contributed 1,100 centipedes from upper Bavaria and Austria, including many specimens otherwise known only from the types; Dr. Nell B. Causey, Fayetteville, Ark., donated 215 centipedes from Arkansas and southeastern United States.

The most important single accession received in the division of neuropteroids consists of a synoptic collection of African dragonflies and damselflies received from Dr. E. C. G. Pinhey, Bulawayo, Southern Rhodesia; 2,421 identified North American aquatic insects were received from Dr. Stanley G. Jewett, Jr., Portland, Oreg.; Dr. A. E. Brower, Augusta, Maine, presented 4,296 caddisflies from northeastern United States; from Fritz Plaumann, Nova Teutonia, Brazil, 4,002 caddisflies were acquired by purchase; Dr. A. B. Gurney, Insect Identification and Parasite Introduction Research Branch, U.S. Department of Agriculture, presented 1,882 grasshoppers and lacewings from Texas and Virginia; Dr. O. S. Flint, Jr., of this division, collected and presented 6,768 caddisflies.

Botany.—An excellent set of 1,859 plants collected on the British Solomon Islands by T. C. Whitmore was received from the Forestry Department at Honiara. Mrs. Paul Bartsch presented the herbarium of the late Dr. Paul Bartsch consisting of 10,220 plants from Iowa and Virginia, many of them of historical interest. Also received as gifts were 482 plants of Bolivia from M. Cárdenas, Cochabamba, Bolivia;

1,055 specimens of Araceae from southeast Asia from Dan H. Nicolson; 2,215 lichens of Florida and Minnesota from Dr. Mason E. Hale; and 945 mosses from Dr. Frederick J. Hermann.

Received in exchange were 4,675 plants, which included many collections of historical importance, such as those of Guadichaud, Sieber, Sodiro, and Vieillard, from the Muséum National d'Histoire Naturelle, Paris; 1,790 specimens mostly collected in northern South America by Bassett Maguire et al., from the New York Botanical Garden; 1,733 specimens from New Guinea, Thailand, and Africa, from the Royal Botanic Gardens, Kew Surrey, England; 1,578 specimens from New Guinea received from the Commonwealth Scientific and Industrial Research Organization, Canberra, Australia; 1,380 plants collected in British Guiana by R. J. A. Goodland, from McGill University; 1,126 plants of Central America from the Escuela Agricola Panamericana, Tegucigalpa, Honduras; 380 fine specimens collected in Argentina by Mydel-Peterson from the Botanical Museum, University of Copenhagen, Denmark; 306 selected specimens of South African plants from the University of Pretoria, South Africa; 500 mosses from the Naturhistoriska Riksmuseet, Stockholm, Sweden; 209 plants comprising issues 85–88 of Schedae ad Herbarium Florae Rossicae, from the Botanical Institute of the Academy of Sciences, Leningrad, U.S.S.R.; 345 woods from the Serviço Florestal, Rio de Janeiro, Brazil; and 187 woods from the Conservator of Forests, Kuching, Sarawak.

A total of 1,347 specimens comprising several collections was received from the Istituto Botánico, Caracas, Venezuela, and 1,142 from the Herbário "Barbosa Rodrigues," Itajaí, Santa Catarina, Brazil, in exchange for names. From the University of Michigan were received 542 grasses collected by Rogers McVaugh, and 2,629 woods from Sumatra, the Philippines, Mexico, and British Honduras, mostly collected by the late H. H. Bartlett.

Transferred from other Government departments were 9,354 specimens of Alaska from the Geological Survey through Dr. Robert S. Sigafoos, and 1,240 plants of Thailand from the U.S. Army at Fort Detrick, Md. Collected for the Museum were 564 plants of Alaska from William J. L. Sladen, Baltimore, Md., 554 grasses collected on Trinidad by Dr. Thomas R. Soderstrom, and 205 grasses collected by Jason R. Swallen in South Africa.

Paleobiology.—In the division of paleobotany important specimens received as gifts include 36 prepared slides containing 84 fossil spore and pollen type specimens from West Africa, from the Jersey Production Research Co. through R. E. Rohn; 11 silicified stems of the tree fern genus *Cyathodendron* from the Eocene of Texas, from S. N. Dobie, Whitsett, Tex.; and a large, well-preserved limb section from

the Eocene of Wyoming from Mr. and Mrs. Jean Case, Dr. F. M. Hueber collected 2,000 specimens of Lower Devonian plant remains from the Gaspé and northern New Brunswick region of Canada, the field work supported by Walcott bequest.

Among the 372,000 specimens accessioned by the division of invertebrate paleontology are a number of collections which are of major importance. Transfers of type specimens from the U.S. Geological Survey included: 160 Cambrian trilobites described by A. R. Palmer; 46 cephalopods from the western interior; conodonts from the Great Basin; corals from the Ordovician of Alaska; and Foraminifera from the Tertiary of Equatorial Africa, and the Gilbert Islands in the Central Pacific.

Gifts included several noteworthy additions. Johns Hopkins University gave 3,700 type specimens described in the well-known Paleozoic volumes of the Maryland Geological Survey stratigraphic series. One thousand specimens of Middle Ordovician and Silurian invertebrates were collected in southwestern Ontario by Dr. and Mrs. G. A. Cooper. Dr. R. S. Boardman completed a major collection of more than 200,000 Paleozoic Bryozoa from a number of measured sections in the Ordovician of Oklahoma. Dr. Franco Rasetti donated 3,500 identified Cambrian trilobites including many type specimens. Dr. A. J. Boucot gave 7,000 Silurian brachiopods collected in Great Britain. A valuable collection of 5,000 mollusks from the Tertiary of Virginia and Maryland was given by Dr. R. J. Taylor.

Other valuable gifts were: 140 specimens of Upper Paleozoic brachiopods from Chihuahua, Mexico, given by Teodoro Diaz G.; a large number of Tertiary mollusks from Hampton, Va., by Dr. T. Walley Williams; 10 specimens of unique Tertiary mollusks from Florida by Mr. and Mrs. J. B. Williams; and an extensive collection of Mississippian endothyrid Foraminifera consisting of more than 1,000 thin sections, including many type specimens, donated by Dr. Edward Zeller.

Funds from the Walcott bequest were used to purchase more than 20,000 invertebrates, one of the world's most complete collections from the Jurassic and Cretaceous of Chile, from Mrs. Elsa de Biese, Santiago, Chile. With the cooperation of the Arabian American Oil Co., and financed partly by Walcott funds, Drs. P. M. Kier and E. G. Kauffman of the Museum staff collected more than 25,000 specimens of a variety of invertebrates from Mesozoic rocks of Saudi Arabia. The Springer fund made possible the purchase of 1,023 blastoids and crinoids from the Burlington limestone of Iowa and Missouri, and 120 Triassic echinoids from the Moenkopi formation of Utah.

Outstanding exchanges brought many important specimens including 1,050 species of Jurassic and Cretaceous mollusks from the Geologi-

cal Survey of Pakistan; 160 plastotypes of Mesozoic mollusks housed at the University de Lyon; 12 species of ammonites from Moscow University; and 50 plastotypes of Upper Cretaceous species in the collections of the Texas Bureau of Economic Geology.

Particular mention is made of a collection of 122 specimens of heterostrachian, acanthodian, and arthrodire fishes from a Lower Devonian quarry in Lucas County, Ohio, received in an exchange with the Chicago Natural History Museum.

An interesting collection of Pleistocene vertebrate remains from Cartersville, Ga., was donated to the Smithsonian Institution by Shorter College of Rome, Ga. The assemblage represented includes at least 20 species and is important as the most extensive Pleistocene vertebrate fauna yet discovered in Georgia.

In the division of vertebrate paleontology two outstanding accessions resulted from field collecting by the staff. Dr. C. L. Gazin assisted by Franklin L. Pearce, collected approximately 350 specimens of early Tertiary mammals. The specimens were taken principally from the Middle Eocene Bridger formation of southwestern Wyoming, but included also are small collections from the Paleocene of the Green River and Fossil basins of southwestern Wyoming and from the Bison Basin of south-central Wyoming. The collections are important for the wealth of small forms, such as Primates, rodents, insectivores, and carnivores from the Middle Eocene beds of the Bridger Basin.

Dr. D. H. Dunkle, assisted by Gladwyn B. Sullivan, collected approximately 307 fossil fishes mainly from new localities in the upper Madera formation of Permian or possibly Pennsylvanian age in central New Mexico and consisting principally of sharks and acanthodian, paleoniscoid, and coelacanth fishes. Other important collections of these forms were obtained from the Pennsylvanian Wea shale in Nebraska and Iowa. In addition, a small collection of *Leptolepis* remains was made in the Jurassic Todilto limestone of New Mexico, and various bones of arthrodires and crossopterygians were collected in a Middle Devonian quarry in Ohio.

Mineral sciences.—In all, 9,230 specimens were received in the division of mineralogy. Outstanding among the many important gifts was an exceptionally fine gem-quality topaz crystal from Brazil, from Oscar Heyman & Brothers, Inc. Other important gifts were scapolite, Madagascar, from John B. Jago; rhodonite, Franklin, N.J., from Mrs. Frank A. Lewis; opal, Australia, from Leland Quick; and tourmaline, Brazil, from Bernard T. Rocca, Sr. Outstanding among specimens received by exchange was a fine example of cuprosklodowskite from the Congo, a very fine large brazilianite crystal from Brazil, and an exceptionally fine, large, gem-quality crystal of beryl, variety aquamarine, also from Brazil.

A total of 4,113 specimens were added to the Roebling collection by purchase or exchange. Outstanding among these were a very large Japanese twin of quartz, from Arizona; a fine specimen of scolecite from Brazil; a crystal of scapolite of unusually large size from Mexico; some fine francevillite and chervetite from Gabon; and some outstanding specimens of raspite from Australia. Acquired by purchase from the Canfield fund was a very large crystal of chrysoberyl from Russia and an extraordinary crystal of danburite from Baja California, Mexico.

Outstanding new additions to the gem collection included a 1,000-carat aquamarine, from Brazil, from Evyan Perfumes, Inc.; a very unusual star sapphire, showing four separate stars, from Ceylon, from Sidney Krandall & Sons; a jade bowl, formerly in the Vetlesen collection, from Mrs. Mildred Tabor Keally; a Mexican opal, from Mrs. Frank A. Lewis; two fine kunzites from Brazil, weighing 296.78 and 336.16 carats, from Robert C. Nelson, Jr.; four diamonds of rare blue and green colors, from Van Cleef & Arpels, Inc.; and a collection of spheres of jade, petrified wood, and other gem materials from Albert R. Cutter. Gems acquired by purchase from the Chamberlain fund for the Isaac Lea collection included a 22.35 carat golden sapphire and a 24.15-carat cat's-eye diopside.

Five very exceptional gems, all from Brazil, were added to the collection by exchange. They were a golden green beryl weighing 1,363 carats, a 914-carat green beryl, a greenish-colored topaz weighing 1,469 carats, a 1,362-carat amethyst, and a heart-shaped kunzite weighing 880 carats. Received from an anonymous donor was the Portuguese diamond, a fine step-cut stone weighing 127.01 carats. The Portuguese diamond is the largest cut diamond from Brazil and the thirteenth largest in the world. In the 1920's it was recut to its present shape from a 150-carat cushion-shaped stone. Details of its early history are unknown, but it is said that it was once owned by the royal family of Portugal.

Eighty-three meteorites were accessioned during the year, 28 of which were not previously represented in the collection, making this the best year in some time. The most important single addition was the collection of the late Arthur R. Allen of Trinidad, Colo. It contained 45 meteorites and 636 grams of tektites and was purchased by a grant from the National Aeronautics and Space Administration. Specimens of particular interest were the 14 fine oriented individuals of the Pasamonte, N. Mex., fall (totaling 1.3 kg.) and a Canyon Diablo specimen containing a large diamond inclusion. Seven stony meteorites that had not been previously known were included: Alamosa, Colo. (1.8 kg.); Blackwell, Okla. (2.4 kg.); Georgetown, Colo. (0.68 kg.); Mosquero, N. Mex. (1.6 kg.); Thatcher, Colo. (2 g.);

Tobe, Colo. (5.4 kg.); and Mosca, Colo. (6.1). Outstanding among the donations was a specimen of the widely publicized Bogou iron presented by President Maurice Yameogo of the Republic of Upper Volta.

Science and technology.—In the division of physical sciences an outstanding accession was the gift from Vassar College of the large telescope built in 1863 by Henry Fitz, one of America's famous telescope makers, and used by Maria Mitchell at Vassar. Preston Bassett gave an 8-sided revolving mirror used by Albert Michelson in his famous determination of the velocity of light in 1924. A Collins helium cryostat, from Loyola University of New Orleans and Arthur D. Little, Inc., and an earlier Collins cryogenic expansion machine, from Samuel C. Collins, are basic artifacts in the recent development of commercially available low-temperature apparatus.

In the section of chemistry, outstanding accessions relating to the element fluorine were a replica of the platinum apparatus for electrolysis and distillation used by Henry Moissan in his epochal isolation of fluorine (1886), and a commercial fluorine cell made by the Harshaw Chemical Co., in 1942–43, and given the Museum by the company. The Moissan apparatus was fabricated through the courtesy of the Baker Platinum Division of Engelhard Industries, Inc.

The collection of adding and calculating machines in the section of mathematics was notably enriched by the gift of 76 specimens from the Victor Comptometer Corp. The gift includes several famous historical machines, such as the Schilt adding machine of 1851, the oldest European key-driven machine; a Bollee direct-multiplication machine, one of only three such machines made by Louis Bollee between 1888 and 1892; and the famous Scheutz difference engine of 1853, the first complete difference engine ever built. A replica of Charles Babbage's difference engine was donated by the International Business Machines Corp.

Among the most outstanding accessions in the section of light machinery and horology was a pocket watch made by Henry and James F. Pitkin of East Hartford, Conn., in about 1838. This specimen is an example of the first American attempt at watchmaking by machines. Other significant acquisitions by this section were a splendid example of a French skeleton clock of the late 18th century and a combination lock patented in 1841 by Dr. Solomon Andrews, an American inventor.

The section of tools acquired the J. R. Brown Linear Dividing Machine of 1859 from the Brown & Sharpe Co., which was a milestone in the history of measurement in American manufacturing. A fully operative reproduction of the gun-stocking lathe developed by Thomas Blanchard in 1820–22 was also received. This pioneer machine, the original of which is in the Springfield Armory in Springfield, Mass.,

represents the beginning of American mass production by machine tools. A rare 19th-century Holtzapffel ornamental turning lathe was acquired with a very comprehensive collection of accessories. Edvard Johansson, Royal Swedish Consul at Detroit, donated a set of Johansson gauge blocks for the hall. The adoption of the Johansson system of gauges invented by his father, C. E. Johansson in the late 19th century, revolutionized mass production by making it possible to achieve universal interchangeability of machine parts. This particular set was the first to be produced in stainless steel and was made especially to be given to the inventor on his 71st birthday in 1933. The presentation was made in a formal ceremony in the hall of tools on March 13 by the Royal Swedish Ambassador, His Excellency Hubert de Besch.

Among the outstanding models received by the division of transportation were a Pacific coast lumber steamer, a 4-masted barkentine, and the schooner *Fly* of 1812. A model of the new class of fast freight steamers, the *American Challenger*, 1962 record holder for the North Atlantic crossing by a freighter, was received from the United States Lines as a gift.

The oldest scale model of an American-built ship, His Majesty's 44-gun ship *America*, built at Portsmouth, N.H., in 1746–1747, was received as a 3-year loan by special agreement from the trustees of the Portsmouth Athenaeum, Portsmouth, N.H. The model will be repaired and exhibited by the marine section and, after a year, transferred to the division of naval history for a 2-year exhibition period.

Three early railway signals (1880–1905) were donated by Thomas T. Taber to the section of land transportation. The vehicle collection was enriched by several important additions. The Mack Bulldog truck (1930) is the first commercial motor vehicle to be added to the collection and was donated by Victor Ottilio & Sons. A fine Rockaway (1860) was the gift of Mr. and Mrs. Carl F. Flemer, Jr. A Hack Passenger Wagon (1880), more commonly called a mud wagon, was also added to the carriage collection.

The largest object accessioned in the division of electricity was an 85-ton alternating-current generator from the Adams station at Niagara Falls, donated jointly by Niagara-Mohawk Power Corp. and Westinghouse Electric Corp. It is this alternator that inaugurated in 1895 the modern era of central stations distributing electrical power over large areas. A somewhat smaller, but very important, magneto generator was received from the University of Virginia. It was made by Hippolyte Pixii in 1832 or 1833 and represents the first use of a commutator for the production of direct current. Only two other machines like this are known to exist in the world. A third generator, by Charles Wheatstone, was obtained on indefinite loan

from King's College, University of London. It is one of the first examples of a self-excited dynamo, a principle discovered coincidentally by Wheatstone in England and Werner Siemens in Germany in 1866. Excellent replicas of four alternating-current motors representing the pioneer work of Galileo Ferraris in 1885 were given to the museum by the Associazione Elettrotecnica ed Elettronica Italiana and Istituto Elettrotecnico Nazionale Galileo Ferraris of Turin.

Among the major accessions during the past year in the division of medical sciences were a collection of tools and research apparatus used in a late 19th century microbiology and biochemistry laboratory, donated by the University of Michigan, and a 1953 hydraulic turbine contra-angle handpiece with accessories and test model for dental drilling from the National Bureau of Standards. Also acquired were the office material, dental instruments, and personal memorabilia of Dr. Charles E. Kells as a gift from his daughter, Mrs. J. O. Pierson, through the School of Medicine of Tulane University. To the pharmaceutical collection, an ancient Egyptian mortar and pestle, weights, and amulets were added.

Civil history.—Several items with Presidential associations received in the division of political history include a pair of leather chaps worn by President Theodore Roosevelt in the Dakota Territory, the gift of Mr. and Mrs. Kermit Roosevelt; a meerschaum pipe used by President Ulysses S. Grant in the White House, from the estate of George W. Crouch; one of the microphones used by President Franklin D. Roosevelt during his "fireside chats" to the American people in the 1930's and 1940's, the gift of the Columbia Broadcasting System and WTOP-Radio, Washington, D.C.; a pen used on January 23, 1964, by President Lyndon B. Johnson to sign the bill establishing the John F. Kennedy Center for the Performing Arts, the gift of Senator Clinton P. Anderson. Important additions made to the First Ladies Collection are two dresses worn by Mrs. Grover Cleveland as First Lady and an evening cape that had belonged to her; these were the gift of Mr. and Mrs. Richard F. Cleveland. One of the new dresses, of black satin and iridescent taffeta, now represents Mrs. Cleveland in the exhibit in the First Ladies Hall.

The division of cultural history received the frame and woodwork of an entire house, the gift of Alexander B. C. Mulholland; built in Ipswich, Mass., the older portion of this house dates from the late 17th century, the later from about 1750. The Honorable David Bruce presented 18-century woodwork and paneling from two rooms of a Charleston, S.C., house. The architecture of Louis Sullivan is represented in one lot of ornaments from his Chicago Stock Exchange Building, given by Mr. and Mrs. Leon M. Despres, and in another lot

from Sullivan's Garrick Building, given by the Joint Committee on Preservation of the Garrick Building Ornament and World Book Encyclopedia. Mr. and Mrs. Fielding Pope Meigs, Jr., presented 223 miscellaneous pieces of furniture, utensils, portraits, and other items, all heirlooms of the Meigs family. Other gifts include 33 rare early maps, a gouache by D. Y. Cameron, a painting by Thomas Wood, and two silver cans by Samuel Edwards, from Mrs. Francis P. Garvan; an 18th-century account and letter book of Alexander Smith of Alexandria, from Mrs. Jean M. Dodd; two mahogany side chairs from Mrs. Wellington Powell; and four side chairs and a Pennsylvania rocking chair from Mrs. George Maurice Morris. The family of Harry T. Peters donated a poster advertising a traveling menagerie from the Zoological Institute of New York City, dated 1835, a rare and early example of its kind.

To the division of numismatics was added an original pewter striking of the noted Castorland token made for the officers of the French colony established at Carthage, N.Y., 1796, and a rare pattern half dollar of 1916, both given by Ben Douglas. Other outstanding additions to the United States series were a $20 gold piece in high relief and a $10 gold piece originally owned by Henry Hering, who completed the design of these coins in 1907 for Augustus St. Gaudens, and Mr. Hering's notes concerning the history of this gold coinage and the interest of President Theodore Roosevelt; these were the gift of Stack's of New York. A die used by the J. J. Conway Co. of Colorado in the striking of a private $5 gold piece was donated by Robert Bashlow. Joseph B. Stack gave tintypes of the Bechtler family, well-known private gold coiners from North Carolina, a daguerreotype of John Little Moffat, a leading coiner in San Francisco during the gold rush, and the notebook of the mint engraver J. B. Longacre concerning the design of the 1856 flying eagle cent.

An important collection of silver bars, bullet money, and various forms of media of exchange used in Siam and China were donated by Mrs. F. C. C. Boyd; Harvey Stack gave the Edith and Jean Jacques Turc collection of necessity pieces issued in France and the French colonies during the 1914–26 period. Willis du Pont added 645 coins struck during the second part of the reign of Catherine II of Russia and 210 Russian silver and bronze medals. Mrs. Wayte Raymond gave 1,167 coins of the world struck during the 19th and 20th centuries Mr. and Mrs. Mortimer Neinken made an important contribution of a specialized collection of checks of United States banks and nearly 10,000 items of European paper currencies and documents of value. The first instance of the use of paper in coinage, a quarter gulden in cardboard issued in Leyden in 1573 during the siege by the Spaniards, was a gift from Dr. V. Clain-Stefanelli.

To the division of philately and postal history Baron Takaharu Mitsui of Tokyo, Japan, donated an outstanding group of early letters and documents pertaining to the private posts of 19th-century Japan and the early government postal service of that country. Morrison Waud of Chicago, Ill., gave a large and comprehensive collection of United States newspaper stamps, proofs, essays, and forgeries and 669 examples of stamped revenue paper. Mr. and Mrs. R. O. D. Hopkins donated a collection of essays and die proofs of the stamps of China and placed additional material of that nature on loan. A large specialized collection of stamps of South Africa was given by Dr. O. L. Harvey. Dr. James Matejka donated early airmail stamps of Syria and a rare airmail stamp of France. Harry L. Lindquist donated a large number of United States and foreign covers, many of which bear special postal markings and commemorative stamps. Charles H. Wuerz, Jr., continued to contribute stamps of Siam in an effort to complete that section of the National Postage Stamp Collection.

Arts and manufactures.—Ralph E. Becker presented to the division of textiles a comprehensive collection of silk Jacquard woven pictures. These interesting examples of an unusual weaving art date from 1867 through the 1930's. The wide variety of subjects include pictures of Columbus sighting America, Betsy Ross stitching the flag, and facsimilies of the signatures of the Declaration of Independence. An excellent collection of American needlework was presented by Dr. Margaret R. Sandels. One of the embroidered pictures, "The Sea Beast," of Mrs. Theodore Roosevelt, Jr., a noted needlewoman, was given by Mr. and Mrs. Sidney de la Rue. A colorful 18th-century floral border by the distinguished French designer Philippe de Lasalle was added to the brocade collection.

Mrs. Clara W. Berwick supplemented her previous gifts to the division of ceramics and glass by 74 pieces of rare early American glass and 22 European and Oriental ivories. Robert H. McCauley presented 65 pieces of Liverpool type transfer printed earthenware, including a number of rare pitchers decorated with American themes. Mr. McCauley is the author of the definitive book *Liverpool Transfer Designs on Anglo-American Pottery.* Mrs. William A. Sutherland continued to add to the division's collection of 18th-century English porcelains. This year she gave 28 fine examples of the production of 10 important factories, including a splendid Derby pitcher and a rare Lowestoft coffeepot. Dr. Hans Syz presented by transfer 53 pieces of 18th-century European porcelain. One of the finest collections in America, the Syz collection is especially notable for examples of the important German factories, such as Meissen, Berlin, Höchst, Frankenthal, and Ludwigsburg, and of the extremely rare Viennese porcelain of the DuPaquier period.

The most important accession received in the division of graphic arts was a bequest of 243 Currier & Ives lithographs of sporting and western subjects from the Adele S. Colgate Estate. This gift greatly enhances the standing of the Museum's collection of Currier & Ives prints. The important gift of Erich Cohn of 20 drawings and etchings by the German expressionist artists Paul Kleinschmidt and Ludwig Meidner reflects what was probably the strongest group contribution to printmaking in this century. The Society of Washington Printmakers donated, through its president, Prentiss Taylor, the intaglio print *Image III*, by Lois Fine; the woodcut *The Valley*, by Isabella Walker; and the lithograph *Nova Scotia*, by Louis Lozowick.

The section of photography acquired a number of historically noteworthy specimens of photographs and equipment. Lucien G. Bull of Paris presented a large group of material related to the early history of high-speed photography, consisting of original negatives, prints, and an electromechanical timing device. Ansco, Binghamton, N.Y., presented a model of a photographic wagon of the type used by Mathew Brady during the Civil War. Nikon, Inc., presented a "Nikonos" 35-mm. underwater camera, with watertight lens and body, for use under water without a protective housing. The *New York Daily Mirror* donated a lightweight Zeiss Ikon, Ernemann plate camera, originally purchased in the 1930's by William Randolph Hearst to replace the bulkier cameras used by his newspapers, and another specially designed camera intended to take pictures from a concealed position.

The division of manufactures and heavy industries continued to collect for the various halls planned for the Museum of History and Technology. New York University presented to the section of nuclear energy the first subcritical reactor to be installed in a teaching institution. Improvised from 2 tons of fuel lent by the U.S. Atomic Energy Commission and installed in a pickle barrel, the university was able to secure at a cost of $1,500 a teaching research facility which might otherwise have been unattainable.

Youngstown Sheet & Tube Co. presented a model of an electric weld pipe mill for the hall of iron and steel. A malleable iron air furnace was given by Erie Malleable Iron Co.; and some Roman nails from the Inchtuthil excavation in Scotland came from Colvilles, Ltd., of Glasgow.

The section of petroleum received further gifts as a result of the excellent work of the American Petroleum Institute's subcommittee. Among these were an animated model of a modern sea-going drilling installation from Kerr-McGee Oil Industries, Inc.; three models of drilling rigs from the Lee C. Moore Corp.; and an interesting survey model of the Velma field from Skelly Oil Co.

The division of agriculture and forest products has been principally concerned with obtaining materials for the hall of forest products. The Forest Products Laboratory, Department of Agriculture, Madison, Wis., gave a swellograph—a device that measures swelling changes in wood having a finished surface. Larus & Brother Co., Inc., reproduced a tobacco hogshead like those used 125 to 150 years ago. Permali, Inc., contributed samples of machined parts for electrical equipment and Fibron Products, Buffalo, N.Y., gave 17 handsome pieces of compressed wood products. To the agricultural collection has been added catalogs of agricultural implement companies around 1880 belonging to Sylvanus D. Locke, the inventor of the famous wire binder. Gordon Dentry donated a four-tined wooden fork used by his grandfather and possibly his great-grandfather in Baltimore County, Md.

Armed Forces history.—A fine example of a Gatling gun was presented by the Armed Forces of Honduras. Mrs. George C. Marshall presented several uniforms worn by General of the Army George C. Marshall during World War II. The division of naval history made significant additions to the national collection of historic warship models while projecting further units required to complete the hall of armed forces history. Particularly notable was a rigged model of Robert Fulton's *Steam Battery*, the world's first steam man-of-war, which was built by Adam and Noah Brown in 1814 for the defense of New York. Plans for this 26-gun blockship were provided by Howard I. Chapelle who in 1961 discovered a contemporary draft of the *Steam Battery* in the Danish Royal Archives at Copenhagen. By happy coincidence, the division of naval history also received an original Fulton draft of the armored torpedo boat *Mute* presented by the family of George F. Brown, descendants of her versatile builders, the Brown brothers of New York. The emergence of the steam navy was further represented with the completion of a superb model of the side-wheel steamer *Powhatan*, which served with Commodore Perry in the opening of Japan.

Through the generosity of the U.S. Coast Guard, the division of naval history received a fully equipped beach cart of the type used by the Life Saving Service for offshore rescue, a set of range lights from Alaska, and an oil painting by Hunter Wood of the topsail schooner *Massachusetts*, first cutter commissioned by the early Revenue Marine.

A patent model of the revolutionary K–1 firing device, the heart of the antenna mine employed in the North Sea mine barrage during World War I, was presented by Mrs. Ralph C. Browne, widow of its gifted inventor. Vivid memories of the Battle of Midway were evoked by the bullet-torn flight jacket and combat decorations donated by George H. Gay, sole survivor of Torpedo Squadron 8.

Among the more important objects acquired by the section of underwater exploration during the year are ships' fittings and equipment from a wreck site in Bermuda believed to date from the 1560's. These include a bar shot, several single blocks, two parrels, small- and medium-sized deadeyes, and a large collection of ceramic sherds, some of which will yield nearly complete vessels when reconstructed.

RESEARCH, EXPLORATION, AND FIELDWORK

Dr. T. D. Stewart, director of the Museum of Natural History, accompanied by exhibits specialist John C. Widener, went to Mexico City in mid-December 1963, the former to select examples of prehistoric filed and inlayed human teeth and the latter to make molds thereof. Mr. Widener will make casts from the molds for an exhibit in the planned hall of physical anthropology.

Dr. Stewart, serving as a member of the Committee on Research and Exploration of the National Geographic Society, inspected the Wetherill Mesa archeological project in Mesa Verde National Park late in June, stopping off enroute from a second trip to Mexico City where he attended the 33d annual meeting of the American Association of Physical Anthropologists.

At various times during the year Dr. I. E. Wallen, assistant director for oceanography, visited institutions in Massachusetts, Rhode Island, New York, Virginia, North Carolina, Georgia, Florida, Mississippi, Louisiana, Texas, California, and Hawaii in connection with the program of the Smithsonian Oceanographic Sorting Center. He also prepared several short papers dealing with developments in oceanography and the role of the Sorting Center.

Dr. H. Adair Fehlmann, supervisor of the Smithsonian Oceanographic Sorting Center, participated in Cruise 4B of the R/V *Anton Bruun*, of the International Indian Ocean Expedition, from early November to mid-December. This trip gave him a useful opportunity to study curatorial procedures on shipboard and to determine the need for a trained technician to oversee the handling of biological samples from the time of collection to the time the specimen cargo is consigned for shipment to the Sorting Center. Thanks to his recommendations, future collections should come through in better condition and with more complete documentation. Dr. Fehlmann also had an opportunity to observe the techniques and equipment used in handling plankton in the Indian Ocean Biological Laboratory at Ernakulam, South India.

Chairman of the department of anthropology Waldo R. Wedel completed a review of the prehistory and aboriginal ecology of north-central Colorado in which he emphasizes the importance of the foothills-hogback strip between the Plains and the Front Range in the

history of the region. In addition, he continued work on two manuscripts, one dealing with the 1961–62 Smithsonian excavations at the Lamb Spring archeological-paleontological site near Littleton, Colo., and the other with the 1952 Smithsonian-Princeton investigations at an ancient bison kill near Cody, Wyo. The latter site has recently been dated by the radiocarbon method at 8,750–8,840 years ago. At the close of the year he was back in the Middle West.

Dr. Clifford Evans, curator of archeology, and research associate Betty J. Meggers completed a major monograph on the Valdivia and Machalilla phases of the Early Formative period of coastal Ecuador. Twenty-two dates obtained by processing shell and charcoal samples in the Smithsonian's Carbon Dating Laboratory convincingly bracket the Valdivia phase at 5,150 to 3,400 years ago.

After joining the staff in December as associate curator of archeology, Dr. Richard B. Woodbury made two trips to the Tehuacán Valley in southern Puebla, Mexico, in continuation of his research on preindustrial systems of water management in arid regions. He found evidence of large-scale irrigation from Late Formative times on, that is, for about 2,500 years—probably the longest record of irrigation in the New World. Dr. Woodbury also continued working with research associate Nathalie F. S. Woodbury on a report dealing with the Hawikuh archeological site in New Mexico, based on the unpublished records obtained in 1917–23 by the late F. W. Hodge, following his departure from the Smithsonian's Bureau of American Ethnology.

In collaboration with Drs. Glen H. Cole of the Uganda Museum and A. Jamme of the Catholic University of America, Dr. Gus Van Beek, associate curator of archeology, completed a preliminary report on an archeological reconnaissance in Wadi Hadhramaut, South Arabia, undertaken in 1961–62. He also spent several weeks during April and May in an archeological reconnaissance in Yemen, at the invitation of the Yemen Arab Republic Government. On the way back to the States he visited sites in Ethiopia and conferred with colleagues in Aden and Jordan.

Museum specialist George Metcalf continued his studies of archeological materials from central Nebraska, encouraged by 11th- to 14th-century site dates supplied by the Smithsonian's Carbon Dating Laboratory. Dr. C. G. Holland, honorary collaborator, having visited 161 archeological sites in southwestern Virginia in 1963, progressed with his analysis of the collections and site data. Honorary research associate Neil M. Judd completed his final monograph (*The Architecture of Pueblo Bonito*) relating to the archeology of Chaco Canyon, N. Mex. During the summer of 1963, Dr. John M. Campbell, honorary research associate, carried out an archeological and ecological survey of the Koyukuk River drainage in northern Alaska. Follow-

ing this trip he continued preparation of a monograph on Nunamiut Eskimo prehistory.

Dr. Saul H. Riesenberg, curator of ethnology, completed a monograph on the aboriginal political organization of Ponape, Caroline Islands. In addition, he progressed with the report on the megalithic structures of Nan Madol, Ponape, where a Smithsonian joint archeological-ethnological field project last year produced finds of unusual interest and made possible an evaluation by different disciplinary approaches.

Intensive exhibit work in the hall of the cultures of Africa and Asia, opened informally at the end of the year, left little time for other research by the associate curators involved, Drs. Gordon Gibson and Eugene Knez. On the other hand, associate curator William Crocker spent 2 weeks in July 1963 and approximately 4 months early in 1964 with the Canela Indians of Brazil, a tribe threatened with extinction. He was again with them as the year ended. Between trips to Brazil Dr. Crocker prepared two articles based on the Canela investigations.

Dr. J. Lawrence Angel, curator of physical anthropology, completed two manuscripts, one on osseous changes in the hip joint and the other on the human skeletons associated with extinct animals at the Tranquility site, California; he completed a paper on *hyperostosis spongiosa* to be included in a volume on paleopathology. With his technical assistant, Donald Ortner, Dr. Angel worked out a special form which will permit rapid coding of data on the anthropology of chronic disease for computer analysis. These data have been obtained mainly in a long-term study of students at Jefferson Medical College in Philadelphia, some of whom were restudied this year.

At the beginning of the year Miss L. E. Hoyme, then museum specialist (now associate curator of physical anthropology), was in England studying 19th-century skeletons of known age and sex at St. Bride's Church, Fleet Street, London, and visiting laboratories of physical anthropology. In July she successfully defended her doctoral dissertation at Oxford University and in December received her degree in absentia.

From the end of January to the beginning of April the chairman of the department of zoology, Dr. Horton H. Hobbs, Jr., participated in the Bredin-Archbold-Smithsonian Biological Survey of Dominica, studying the fresh-water decapod crustaceans of the island. As time permitted, he completed a manuscript on new entocytherids from Virginia and made progress on a revision of the entocytherid ostracods of Mexico and Cuba.

Senior scientist Fenner A. Chace, Jr., completed a study initiated by the late Belle A. Stevens on the mesopelagic caridean shrimp *Notostomus japonicus* Bate in the northeastern Pacific. Also, he

finished a report on the decapod crustaceans of the island of St. Helena in the South Atlantic.

Although the curator of mammals, Dr. David H. Johnson, was responsible for the general development of exhibits in the hall of osteology opened at the end of the year, he found time to study the distribution of hares and certain species of bats in southeastern Asia and to continue his general survey of the mammals of that area.

For the better part of the year, Dr. Henry W. Setzer, associate curator of mammals, directed from Washington the work in Iran and southern Africa of field parties collecting mammals and their ectoparasites. This program was carried out in cooperation with the Army Medical Research and Development Command. Dr. Setzer joined the African party in mid-September and the Iranian party in late October, staying until mid-December. His museum work consisted chiefly of identification of mammals from Egypt and the Sudan collected by a Naval Medical Research Unit.

From January to March Dr. Charles O. Handley, Jr., associate curator of mammals, collected specimens in the high mountains on the Colombian frontier of Darién Province, Panama, obtaining among other valuable materials, two species of bats new to the Panamanian fauna and a number of rare marsupials, shrews, and rodents. Late in June, in connection with attendance at a meeting of the American Society of Mammalogists in Mexico City, Dr. Handley spent 8 days studying fruit bats in the Instituto de Biología. This filled one of the last major gaps in his revision of this large and complex genus.

Dr. Robert A. Traub of the University of Maryland Medical School, honorary research associate in the division of mammals, was in Pakistan from the beginning of the fiscal year until October collecting mammals and other vertebrates and their ectoparasites in continuation of his studies of rickettsial infections.

The Pacific Ocean Biological Survey Program, under the direction of Dr. Philip S. Humphrey, curator of birds, has increased greatly in scope since its inception in October 1962. Because of its concern with the distribution, migrations, and ecology of central Pacific sea birds, collaborative relationships have been developed with the U.S. Bureau of Commercial Fisheries, the Bernice P. Bishop Museum, the State of Hawaii Division of Fish and Game, and others. Of approximately 50 people employed this year on the project many were graduate students who were gathering data for doctoral dissertations.

The Rockefeller Foundation has provided support for a field study enabling Dr. Humphrey to work with the Belém Virus Laboratory, Fundação Serviço Especial de Saúde Pública, and the Museu Paraense "Emilio Goeldi," Belém, Brazil. This cooperative field study deals with the relationship of birds and arthropod-borne virus diseases. As

time permitted, Dr. Humphrey continued his studies of plumage succession in birds and on the distribution, ecology, and classification of Patagonian and Brazilian birds. At the close of the year he was back in Brazil.

From the beginning of December 1963 to the latter part of March 1964, George E. Watson, associate curator of birds, served as official United States representative (observer) with the Chilean-Antarctic Commission. During delays in Chile for ship repairs and for the ice to break up he was able to spend 13 days in December at Peulla, Llanquihue Province, observing and collecting forest birds. During another delay of 22 days in January-February at Puerto Williams, he was able to make a catalog of birds breeding on Navarino Island and to collect specimens, among which are several important additions to the national collections. Mr. Watson's observations of birds made on shipboard in Antarctic waters will be useful in preparing an identification guide to Antarctic birds which he has planned. Upon his return from Chile he completed his doctoral dissertation dealing with ecology and evolution of passerine birds on the islands of the Aegean Sea and received in June the Ph.D. degree from Yale University.

Dr. Richard L. Zusi, associate curator of birds, spent a week in November at the University of Michigan working on three manuscripts, which he had begun there, and consulting with Dr. R. W. Storer concerning their joint research project on the myology of grebes. From January to April he was in Dominica studying birds as a participant in the Bredin-Archbold-Smithsonian biological survey of that island.

In continuation of his long-term field work on the birdlife of the Isthmus of Panama, Dr. Alexander Wetmore, honorary research associate and retired Secretary of the Smithsonian Institution, concentrated his efforts from January through March in Darién Province, mainly in the heavy rainforest adjacent to the Colombian boundary. The results were most successful, for both specimens of and observations on species that have been little known in Panama were obtained, and several new records of South American birds not previously recorded in the area were established.

Dr. Herbert Friedmann, honorary research associate and former curator of the division, continued his work on brood parasitism and completed a manuscript dealing with evolutionary trends in the avian genus *Clamator*.

Herbert G. Deignan, honorary research associate and former member of the division, was in Washington from mid-January to late April studying birds from Formosa in the Naval Medical Research Unit (NAMRU) collections and those from Viet-Nam and Cambodia collected by Bernard Feinstein, former museum specialist in the division.

Two new honorary research associates appointed this year, Prof. D. S. Rabor of Silliman University, Philippine Islands, and Dr. Robert W. Ficken of the University of Maryland, carried on important research. Prof. Rabor worked on the general ornithology of the Philippine Islands; Dr. Ficken undertook extensive field and laboratory research on the behavior of wood warblers.

Honorary research associate Oliver L. Austin, Jr., continued his technical editorial work on the two final volumes of A. C. Bent's *Life Histories of North American Birds*.

Dr. Doris M. Cochran, curator of reptiles and amphibians, in collaboration with Dr. C. J. Goin of Gainsville, Fla., made considerable progress on a manuscript dealing with Colombian frogs.

The curator of fishes, Dr. Leonard P. Schultz, accompanied by exhibits specialist Alfred Strohlein, spent a few days in October in the vicinity of Seattle, Wash., in search of a salmon-spawning area that would provide material for a diorama for the planned hall of cold-blooded vertebrates. They were successful and in addition returned with an 89-pound octopus, donated by the Point Defiance Aquarium at Tacoma. Otherwise Dr. Schultz continued his study of frogfishes and his recording of shark attacks throughout the world.

Two associate curators of the division of fishes, Drs. Robert H. Gibbs, Jr., and Ernest A. Lachner, participated this year in cruises of the International Indian Ocean Expedition. Dr. Gibbs was on Cruise 3 of the R/V *Anton Bruun*, the primary purpose of which was to sample deep-sea ichthyofauna in the western Indian Ocean and to relate the distributions of species and biomass to the physicochemical and biological properties of the water masses sampled in a north-south transect. The cruise began at Bombay on August 8 and terminated at Port Louis, Mauritius, on September 20. Following the cruise Dr. Gibbs spent 2 months working at museums in Paris, Berlin, Hamburg, Bremerhaven, and Copenhagen.

Dr. Lachner was on Cruise 4B of the same ship, the major objective of which was to evaluate the relative distribution and abundance of benthic organisms inhabiting the continental shelf and upper slope of the Arabian Sea. This cruise began at Bombay on November 12 and terminated off the Muscat coast of Arabia in mid-December. On his way to and from the cruise Dr. Lachner visited institutions in London, Paris, Bern, Jerusalem, Karachi, Sydney, Brisbane, Hong Kong, and several places in Japan.

Dr. Victor G. Springer, associate curator of fishes, expanded his studies on sharks, completing revisions of three genera. During the year he visited Stanford University and musems in Hamburg, Paris, and London, studying blennioid fish types and other specimens and bringing close to completion a revision of the genus *Entomacrodus*.

Dr. William R. Taylor, associate curator of fishes, developed a new technique in the preparation of specimens for osteological study involving the use of solutions of the enzyme trypsin buffered with sodium borate. This treatment, which removes the muscle tissue, has proved effective in making both preserved and fresh specimens translucent; the connective tissue, cartilage, bones, viscera, and major nerves remaining.

Associate curator Stanley H. Weitzman completed a study of two genera of Asiatic minnows, three manuscripts dealing with South American catfishes, and a study of the osteology and relationships of the characid subfamilies Lebiasininae and Erythrininae.

Dr. J. A. F. Garrick, honorary research associate, who worked in the division of fishes last year, returned to his home in Wellington, New Zealand, where he is continuing his world revision of carcharhinid sharks. During May he visited Australia to study specimens of sharks not available in museums of Europe, America, or Africa. His critical revision of carcharhinid sharks is the first ever attempted.

From the end of December 1963 to mid-February 1964 Dr. Donald F. Squires, curator of marine invertebrates, was a participant in the "MacQuarie Gap" cruise of the New Zealand Oceanographic Institute aboard HMNZS *Endeavour*. Although the nominal purpose of the cruise was to determine the topographic relationship between the MacQuarie Ridge and New Zealand, considerable marine biological work was scheduled. To Dr. Squires's profit, 11 of the 79 bottom dredgings and bottom trawls contained living corals. Through use of the ship's refrigerators, these were kept alive for up to 10 days, thus advancing culturing techniques. The most significant advance in marine knowledge resulting from the cruise was the location and dredging of the first deep-water coral structure found outside the North Atlantic.

In the museum, Dr. Squires finished, with the assistance of Ian W. Keys, senior paleontological technician, New Zealand Geological Survey, a study of the biomechanics of the scleractinian coral *Manicina areolata*. He also completed several other studies on fossil and recent corals.

Associate curator Thomas E. Bowman completed an account of an arostrate population of the planktonic calanoid copepod *Acartia lilljeborgii*, from St. Lucia, West Indies. He described a new genus and species of cirolanid isopod from Madison Cave, Va., the first troglobitic cirolanid to be found in the United States outside of Texas; a new anthurid isopod from the Caguanes Caves in Cuba; and a new mysid crustacean, abundant in Lake Ponchartrain, La. With L. J. Lancaster, he described a bloom of the planktonic blue-green alga *Skujaella* in the Tonga Islands.

During most of April and May associate curator Charles E. Cutress, Jr., accompanied by Kjell Sandved serving as photographer,

collected marine materials along the coasts of Hawaii and southern California to be used in planned exhibits. Following this trip Mr. Cutress visited the Friday Harbor Laboratory of the University of Washington in search of clarification of the taxonomy of the swimming anemones *Stomphia.*

Dr. Raymond B. Manning, who joined the staff at the end of last year as associate curator of marine invertebrates, in May and June teamed with a research group from the Institute of Marine Science, University of Miami, for a 20-day offshore scientific cruise in the Gulf of Guinea. Following the cruise he spent several days collecting inshore marine invertebrates near Dakar, Senegal, before visiting natural history museums in Paris, Leiden, and London to study types of stomatopod crustaceans.

During the year, Dr. Manning finished most of a manuscript revising the stomatopods of the western Atlantic, collaborated with L. B. Holthuis, of the Rijksmuseum van Natuurlijke Historie, on a contribution dealing with stomatopods for the publication "Treatise on Invertebrate Paleontology," and completed two additional manuscripts on these animals.

Associate curator Marian H. Pettibone completed a revision of the polychaete family Pilargiidae, including a description of three new species from Virginia.

Museum specialist Henry B. Roberts completed a description of a new genus of Cretaceous crab, redescribed the Cretaceous crab *Campylostoma pierrense* Rathbun, and compiled a checklist and bibliography of the Pleistocene decapods of the Atlantic and Gulf Coastal Plain.

Dr. Waldo L. Schmitt, honorary research associate, completed the revision of "Crustaceans," a popular account prepared a few decades ago for the Smithsonian Scientific Series.

Curator Harald A. Rehder continued work on a study of the marine mollusks of Polynesia. He sorted and arranged the material he gathered in Tahiti last year, and identified and studied specimens from Tongo and Hawaii. A bibliography of Polynesian marine malacology was initiated, and progress was made on his monograph of the Harpidae and on a study of certain species of the family Volutidae.

From late October to late December, Dr. Joseph Rosewater, associate curator of mollusks, participated in the International Indian Ocean Expedition, Auxiliary Cruise "A" aboard the R/V *Te Vega.* After a delay of 2 weeks in Singapore for ship repairs, which gave him an opportunity to make local collection, the ship headed north through the Straits of Malacca along the west coast of Malaysia with stops at Kuala Lumpur and Penang, then to Phuket, Thailand, and north to the Similan Islands, westward to Sumatra and southeast-

ward down the Mentawai Islands south of Sumatra as far as Mega. Unfortunately, a break in the drive shaft occurred about 60 miles southeast of Padang, cutting the cruise short by about 2 weeks. However, there was obtained in the areas visited a representative collection of mollusks in which new records and range extentions already have been noted.

Associate curator Joseph P. E. Morrison completed a manuscript describing new species of the families Hydrobiidae, Pyramidellidae, and Mactridae, from Louisiana.

Dr. J. F. Gates Clarke, chairman of the new Department of Entomology, accompanied by Mrs. Clarke, visited the island of Rapa (Austral group) in French Polynesia from the beginning of September to mid-December. A large collection of Microlepidoptera and other insect groups was obtained, including 760 specimens reared by Mrs. Clarke. Also, the food plants of more than half of the approximately 75 species collected were ascertained and immature stages of all reared species were preserved. This is the first time that such information has been available for these small moths. A preliminary examination of the Microlepidoptera from Rapa suggests a close relationship with those in New Zealand and the Indo-Australian area.

In June Dr. Clarke spent 5 days on Mount Magazine in the Ozark National Forest of the Ouachita Mountains, Ark. The nearly 3,000 specimens he collected, of which 1,222 are Microlepidoptera, help fill a gap in the national collection.

Dr. Clarke completed a paper on the genera *Orsotricha* and *Palinorsa* of the families Gelechiidae and Oecophoridae, respectively.

Associate curators of Lepidoptera Don R. Davis and W. Donald Duckworth made a joint collection trip from early July to mid-August to a hitherto poorly collected area in northeastern Mexico that extends along the main highway south from Nuevo Loredo and eastward to the Gulf coast between Tampico and Tuxpan. Interest centered primarily on the microlepidopterous families Prodoxidae and Stenomidae with the result that much larval material was collected and many new records acquired. The total collection, including representatives of other insect groups, amounts to approximately 25,000 specimens.

From mid-April to the end of May, Dr. Duckworth again went into the field, this time to Barro Colorado Island, Panama. Through the help of Mrs. Duckworth another 25,000 specimens were collected here.

Dr. Davis completed a revision of the subfamily Prodoxinae and Dr. Duckworth completed several papers dealing with the large family Stenomidae.

In July associate curator of Lepidoptera William D. Field made a 28-day collecting trip for Rhopalocera through the mountains of New York and New England. Large series of several species of butterflies

needed for the national collection were taken. In May Mr. Field spent 12 days in the entomologically neglected area of western Virginia and West Virginia collecting information, especially on the extent of the ranges of boreal species in the southern mountains.

At the close of the year Dr. O. L. Cartwright, curator of Coleoptera, was on a trip to London and Paris to study type specimens of scarab beetles of the Bahamas and Micronesia.

Dr. Paul J. Spangler, associate curator of Coleoptera, spent 7 weeks during July and August in Mexico and southwestern United States collecting much needed material for his investigations on water beetles. So little is known about the merging of the Nearctic and Neotropical Zones in Mexico that all expeditions to this area are pointed toward the elucidation of this factor. Not less than 6 of the genera collected represent new records for Mexico and not less than 20 species are new to science. Larvae for nearly all the species were collected, and all the information on immature forms is new. Specimens of semiaquatic beetles of the very rare family Georyssidae were collected in quantity.

Ralph E. Crabill, Jr., curator of Myriapoda and Arachnida, was in Europe at the beginning of the fiscal year and stayed there until mid-August, during which time he visited the Zoologische Samlung des Bayerischen Staates, Munich, and the British Museum (Natural History) for the purpose of studying typical and ordinary chilopod specimens. In upper Bavaria and northern Austria he undertook four collecting trips which netted some 1,200 specimens, including some topotypes and a host of species not previously represented in the national collections.

From mid-July to mid-August, Dr. Oliver S. Flint, Jr., associate curator of neuropteroids, was on a field trip to the islands of Jamaica, Dominica, St. Lucia, and Grenada, conducting studies on the Antillean caddisfly fauna. During 4 days spent on Jamaica and about a week each on the other islands he collected 2,000–3,000 insects, of which 500 or more are Trichoptera. In April and June he was back in Dominica as a participant in the Bredin-Archbold-Smithsonian biological survey of that island. Dr. Flint completed two papers dealing with certain species of Nearctic Trichoptera in the collection of the Museum of Comparative Zoology, Cambridge, and new species discovered in the United States.

Jason R. Swallen, chairman of the department of botany, visited South Africa in September and October at the invitation of the National Botanic Gardens of South Africa to join in the Golden Jubilee Celebration of the Gardens. The celebration included over a month's tour of the country, which afforded an opportunity to collect about 200 specimens of grasses, including a number of species new to the National Herbarium.

Associate curator of phanerogams Velva E. Rudd continued work on her manuscript on the papilionoid legumes of Mexico, bringing part one to completion. In connection with her studies in the Leguminosae, she spent 6 days in September at the herbarium of the Universidad Nacional Autónomo de México in Mexico City. This research opportunity was afforded by her attendance at the Secundo Congreso Mexicano de Botánica, which met in San Luis Potosí.

From mid-June through August, Dr. Stanwyn G. Shetler, associate curator of phanerogams, traveled to Alaska and collected plants in the western Brooks Range with a University of Alaska expedition. He also studied collections in the herbarium of the University of Alaska and searched for a suitable setting for a diorama planned for the hall of plant life.

Associate curator of phanerogams Wallace R. Ernst completed a manuscript on "The Genus *Eschscholzia* in the South Coast Ranges of California" and, with Dr. H. J. Thompson of the University of California, Los Angeles, another manuscript on the pollination patterns and taxonomy of the genus *Eucnide*. At the American Institute of Biological Sciences (AIBS) meetings at Amherst, Mass., in August his joint paper with Dr. Thompson won an award in taxonomy. During the last 3 months of the year he was in Dominica, participating in the Bredin-Archbold-Smithsonian biological survey of that island.

Associate curator of phanerogams Dan H. Nicolson, along with associate curators Stanwyn Shetler and David Lellinger, visited the Great Smoky Mountains National Park in May in search of sites usable in preparing an eastern deciduous forest life-group in the planned Hall of Plant Life.

At the beginning of the fiscal year Dr. Thomas R. Soderstrom, associate curator of grasses, was in the Wilhelmina Mountains of Surinam, on a New York Botanical Garden expedition which collected until October. About from 5 to 8 percent of the collections represent grasses, all of which, including duplicates, are being identified in the National Herbarium for distribution to major herbaria.

C. V. Morton, curator of ferns, spent 3 weeks during July in libraries in London and Paris checking bibliographic information in connection with his study of the photographs he made of fern types in European herbaria. With associate curator David B. Lellinger, he prepared a treatment of the genus *Asplenium* in Venezuela, based largely on the extensive collections assembled from the Guayana Highlands region by the New York Botanical Garden and the Chicago Natural History Museum.

In August, on his way to the AIBS meetings in Amherst, Mass., Dr. Mason E. Hale, curator of cryptogams, collected lichens in northwestern New Jersey, in the Catskill Mountains in New York, and in

western Connecticut. During September and October he visited major herbaria in London, Stockholm, Uppsala, Lund, Turku, Helsinki, Leiden, Vienna, Munich, and Geneva. One of the purposes of the trip was to subject type specimens to chemical tests. In April Dr. Hale collected in southwestern Virginia, North Carolina, eastern Tennessee, Alabama, and Georgia, obtaining for chemical analysis approximately 1,000 specimens at 27 localities.

Associate curator of cryptogams Harold E. Robinson spent 3 months, from the end of January to the end of April in Dominica, as a participant in the Bredin-Archbold-Smithsonian biological survey of that island. Collections were made of both plant and animal material, including primarily bryophytes, with approximately 200 species, and Dolichopodidae, with approximately 90 species.

Associate curator of cryptogams Paul Conger completed a manuscript on a new species of epibenthic marine diatom from Honolulu Harbor, Hawaii.

Before resigning in August, associate curator Richard E. Norris completed a second cruise on the R/V *Anton Bruun* in the Indian Ocean and made a collection of marine algae and plankton, which is being processed at the Smithsonian Oceanographic Sorting Center.

Dr. William L. Stern, curator of plant anatomy, was transferred temporarily to the International Civil Service early in July so that he could spend a year in the Philippines as a forestry officer with the Food and Agricultural Organization of the United Nations.

On August 25, Dr. Richard H. Eyde, associate curator of plant anatomy, took part in an AIBS pre-meeting botanical field trip through the Berkshire Mountains. He also spent a long weekend in April visiting the Brookgreen Gardens in South Carolina for the purpose of obtaining preserved flowers of *Nyssa aquatica*, a species which does not grow in the Washington area. He arranged for additional flowers to be collected as they appear.

Dr. Eyde completed a comparative anatomical investigation of the flower *Garrya*, an American genus of debated affinities, concluding that the closest allies are the Old World cornaceous genera *Aucuba* and *Griselina*.

Dr. G. A. Cooper, chairman of the department of paleobiology, in company with Dr. J. T. Dutro of the U.S. Geological Survey, made a field trip to New Mexico and Texas from mid-March to the latter part of April. They worked on the Devonian sequence in New Mexico, first at Silver City, and then at Hillsboro, Mud Springs and Caballos Mountains, and Alamogordo (San Andres and Sacramento Mountains). In Texas they collected blocks of fossil-bearing Permian rocks in the Guadalupe and Glass Mountains. Lastly, they collected Permian and Pennsylvanian fossils in the vicinity of Santa Anna and Jacksboro, Tex.

In collaboration with Dr. R. E. Grant of the U.S. Geological Survey, Dr. Cooper nearly finished a large manuscript on the Permian brachiopods of the Glass Mountains.

Dr. Francis Hueber, associate curator of paleobotany, made two trips to Canada this year in connection with his study of fossil plants. On the first trip, in August, he studied sites in Lower Devonian sediments along the shore of the Restigouche River in New Brunswick and type localities for certain species along the north shore of Gaspé Bay in Quebec. Sixteen crates of specimens were forwarded to the museum. His second trip, in May, took him to the Redpath Museum at McGill University, Montreal, and to the Geological Survey of Canada, Ottawa, to examine collections. One of his findings during the second trip is that the holotype of *Cladoxylon dawsoni*, an Upper Devonian plant from New York, is distributed among three separate museum collections.

Dr. Hueber spent the first week in April in Scotland examining collections of Rhynie Chert offered for sale. This is a classic Middle Devonian plant-bearing material no longer freely available from the type locality in Aberdeenshire. It contains exceptionally well-preserved and nearly intact examples of early land plants, the discovery and description of which in 1917–21 revolutionized botanical evolutionary thought. Thus the opportunity to select this material in quantity is quite rare. The lot purchased weighed 1,000 pounds.

Curator of invertebrate paleontology Richard S. Boardman, accompanied by museum specialist George T. Farmer, made a collecting trip to the Arbuckle Mountains in southern Oklahoma in September and October. The oldest known (approximately 480 million years) fossil Bryozoa on the continent occur here in sedimentary rocks 1,500 feet thick. Thus, enough time is represented to demonstrate the evolution of early genera and the phylogenetic connections and origin of many of the genera occurring more commonly in younger rocks.

Dr. Porter Kier, associate curator of invertebrate paleontology, was in Florida at the beginning of the fiscal year and continued there until July 12 studying the living habits of echinoids in the area of the Florida Keys. In company with Dr. Norman Sohl of the U.S. Geological Survey, he used SCUBA diving equipment to observe species distribution in relation to bottom conditions and depth. In April he transferred these investigations to Dominica as part of the Bredin-Archbold-Smithsonian biological survey of that island. Museum investigations enabled Dr. Kier to complete a major study of the evolutionary trends in Paleozoic echinoids.

Associate curator of invertebrate paleontology Richard Cifelli completed a paper on planktonic Foraminifera from the western Atlantic and another on concentration techniques of shelled organisms from plankton.

Associate curator of invertebrate paleontology Erle G. Kauffman and museum technician G. R. Paulson were in northern New Mexico at the beginning of the fiscal year, measuring sections and collecting mollusks from typically early Upper Cretaceous rocks. Shortly thereafter they extended the work into Colorado until the end of July. Approximately 4,000 specimens were obtained from 21 stratigraphic sections measured and collected. The data will permit revision of the Coloradoan stratigraphy in many areas of northern New Mexico and central Colorado, formation of a refined faunal zonation throughout the region, and precise correlation of the sequence across the Front Range of the Rocky Mountains.

Dr. Kauffman, accompanied by Dr. N. F. Sohl of the U.S. Geological Survey, spent the last half of March in Puerto Rico studying the Cretaceous biostratigraphy of the island and collecting invertebrate fossils. All major Cretaceous localities in southwest Puerto Rico, and along the central cordillera, were visited during the course of the work. Approximately 2½ tons of fossil material were collected, predominantly limestone blocks containing silicified mollusks, corals, sponges, and other invertebrates. These collections, added to those obtained previously by Survey personnel, form the largest and most diverse assemblage of invertebrate fossils from the Caribbean Cretaceous.

Dr. Martin A. Buzas, who joined the staff late last year as associate curator of invertebrate paleontology, completed manuscripts on the Foraminifera from a late Pleistocene clay near Waterford, Maine, and a distributional study of the species of Foraminifera in Long Island Sound.

Dr. C. L. Gazin, curator of vertebrate paleontology, accompanied by Franklin L. Pearce, chief of the laboratory of vertebrate paleontology, began exploration of the Middle Eocene Bridger formation of southwestern Wyoming at the beginning of the fiscal year. Unfortunately, at the end of the first week Mr. Pearce became ill and had to return to Washington for hospitalization. Dr. Gazin continued alone until early August. He devoted much time to a careful search for smaller mammals in the upper part of the formation, as exposed in the upper basin of Sage Creek, with some attention to the lower levels in the Grizzly Buttes and to the north of Cedar Mountain. He also made occasional profitable trips to localities of earlier years in the Paleocene and Early Eocene of adjacent basins. At the close of the year Dr. Gazin and Mr. Pearce were engaged in another field trip to New Mexico and Wyoming.

Dr. Gazin completed his morphologic study of the Early Eocene condylarthran mammal *Minicotherium*. This includes a detailed review of nearly the entire skeleton, which is compared with that of other condylarths, of which *Hyopsodus* provides much new information.

From the beginning of September to mid-October associate curator of vertebrate paleontology D. H. Dunkle, accompanied by museum technician G. B. Sullivan, conducted field work in northwestern Ohio, in the area around Council Bluffs, Iowa, and in the Manzano Mountains of central New Mexico. The 370 specimens collected and the stratigraphic observations made will permit important additions and revisions of the known paleoichthyological faunas of the Middle Devonian silica shale of Ohio and several Late Paleozoic horizons of the midcontinent and Rocky Mountain regions. The New Mexico occurrence investigated is of especial interest; it is practically the one known source in North America of a varied marine assemblage of well-preserved fishes, invertebrates, and plants of the Permo-Carboniferous interval.

In September associate curator of vertebrate paleontology Nicholas Hotton III left Washington for field work in Africa. In addition to collecting in the Permo-Triassic beds of the Karroo region of South Africa, which has yielded a variety of mammal-like reptiles, he carried on during a greater part of the year a detailed stratigraphic study of the Beaufort series with a view toward a better understanding of the distribution and ecology of the forms. At the end of the year he had left Africa for Europe to study at certain of the leading museums.

On December 18, 1963, Dr. Clayton E. Ray joined the staff as associate curator of vertebrate paleontology. During the next few months, in continuation of his studies of fossil and modern terrestrial vertebrates, especially rodents, of the Antillean region, he completed reports on a new species of capromyid rodent and an undescribed miniature ground sloth, both from a cave in the Dominican Republic. From mid-May to the latter part of June he conducted a field investigation of Pleistocene occurrences in the vicinity of Puebla, Mexico, in collaboration with an archeological party from the Peabody Museum in Cambridge, Mass.

On three occasions during the year Dr. Remington Kellogg, honorary research associate, made day-long trips to the Chesapeake Bay area, in company with one or more members of the staff, to inspect exposed remains of Miocene vertebrates. The trip in July to Parker Creek, Calvert County, Md., yielded a good part of the skeleton of a Miocene cetothere (*Mesocitus cephunculus*) which is especially useful to Dr. Kellogg in connection with studies now in progress on this group of extinct whalebone whales. The trip to King George, Va., in May revealed a shoreline concentration of mixed and abraded porpoise and sea-cow bones and a variety of shark teeth. Inland occurrences such as this are only rarely encountered, and the distribution record is of interest. In the course of the year Dr. Kellogg completed a report on the skeleton of one of the larger Calvert Miocene whalebone whales.

Chairman George Switzer of the department of mineral sciences completed his annual review of the diamond industry and, with analytical chemist Roy S. Clarke, Jr., et al., completed a manuscript on "Fluorine in Hambergite."

Dr. Paul E. Desautels, associate curator of mineral sciences, completed a study of one of the rare uranium minerals known as "sklodowskite," a hydrous magnesium uranyl silicate, from a new locality in Mexico.

At the beginning of the year associate curator of mineral sciences Dr. E. P. Henderson was in Australia prospecting for meteorites and tektites. He continued working there until October, in company with Dr. Brian Mason of the American Museum of Natural History, New York, and Dr. R. V. Chalmers of the Australian Museum. They collected meteorite material from four well-known Australian craters, Henbury, Boxhole, Wolf Creek, and Dalgarange; relocated the Dalgety Downs meteorite and recovered nearly 500 pounds of material; and collected many fine tektite specimens. Exchanges arranged during the stay in Australia, and on the return trip through the Middle East and Europe, added a number of fine new specimens to the collections. At the close of the year Dr. Henderson was back in Australia on another prospecting trip.

Dr. Henderson completed two manuscripts: one, a study of the hexahedrite meteorite groups, and the other, a discussion of the legendary and probably nonexistent Port Orford, Oreg., meteorite. He also completed a metallographic study of the Bogou, Upper Volta, iron meteorite.

Analytical chemist Roy S. Clarke, Jr., in cooperation with R. J. Gettens and E. W. FitzHugh of the Freer Gallery of Art, investigated an iron-oxide corrosion product of a metal blade in the Gallery's collection and proved that it was fabricated from meteoritic iron. He also completed chemical analysis of the mineral "phosphyllite" from Bolivia.

Silvio A. Bedini, curator of mechanical and civil engineering of the Museum of History and Technology, toured technical museums and other institutions of learning in Great Britain and on the continent, presenting lectures at the Astrophysical Observatory in Arcetri and at the Instituto Nazionale della Ottica in Florence. Later, in collaboration with Francis R. Maddison of the Museum of the History of Science at Oxford University, he completed a book on the de Dondi astrarium entitled "Mechanical Universe." Mr. Bedini completed three more articles about antique science instruments in the national collections; also articles on the invention of the orrery (including study of an unrecorded instrument recently discovered in an American collection), on the evolution of science museums, and on early

Italian science museums. In addition, he competed articles on Galileo's preoccupation with the measurement of time, on a comparison of Galileo's instruments, and on the craftsmen who produced the instruments used by Galileo.

Associate curator Edwin A. Battison, assisted by summer intern Bruce H. White, completed the first draft of a translation of Jacques Besson's *Theatrum Instrumentarum et Machinarum* from the 16th-century French. This significant contribution to the history of technology has not previously been available in English.

Curator of transportation Howard I. Chapelle made three trips to Spain to inspect the reconstruction of Columbus's *Santa Maria* being produced by the Cardona Yard in Barcelona for exhibition at the World's Fair in New York, and to do research on Spanish shipbuilding of the 18th and early 19th centuries.

Grace Rogers Cooper, curator of textiles, completed her monograph on the Robertson and the Clark dolphin and cherub sewing machines of the 1850's. At the end of the year she was studying textiles at the Rijksmuseum, Amsterdam, the Netherlands.

Paul V. Gardner, curator of ceramics and glass, visited 64 museums, private collections, and glass factories in 11 European countries between September and December, to evaluate the recently donated Syz collection of 18th-century porcelains, to meet and confer with collectors and museum personnel in the ceramic and glass field, and to examine new exhibit techniques used in ceramic and glass displays.

Jacob Kainen, curator of graphic arts, made trips to Sarasota, Philadelphia, and New York City for material relating to his study of the Dutch engraver Hendrick Goltzius (1558–1617). He served as juror for two art exhibitions: the 1963 All-Army Art Contest at Fort George G. Meade, Md., and the 25th National Exhibition of the Society of Washington Printmakers. He also had an exhibition of his own paintings at the Roko Gallery in New York City.

On a trip to Europe, Eugene Ostroff, associate curator in charge of the section of photography, visited museums, photographic equipment factories, dealers, galleries, private collectors, and photographers for the purpose of acquiring apparatus and prints for exhibits and of establishing contacts for exchanges.

Peter C. Welsh, curator under the chairman of the department of civil history, completed three manuscripts bearing the following titles: "The Metallic Bench Plane: An American Contribution to Hand Tool Design," "Hand Tools as Decorative Objects," and "Woodworking Tools: 1600–1900."

Assistant curator Doris Esch Borthwick completed a typescript of the letters of Charles Wilkes, leader of the United States Exploring Expedition.

Keith M. Melder, associate curator of political history, completed a biographical sketch of Mrs. Josephine S. Griffing, a 19th-century American reformer and feminist, and revised his manuscript on "Bryan the Campaigner."

The division of cultural history joined the Corning Museum of Glass, serving as principal sponsor, in a second 10-day archeological investigation of the site of John Frederick Amelung's New Bremen Glassworks, which operated between 1785 and 1795 in Frederick County, Md. Ivor Noel Hume, research associate, was archeological director, with Paul N. Perrot, director of the Corning Museum, as administrative director. John N. Pearce, associate curator, and Richard J. Muzzrole, archeological aide, represented Smithsonian participation. The excavations revealed an astonishingly complex foundation structure, evidence of a complete factory unit, having two furnaces, fritting areas, and the other appurtenances of a typically Germanic glass-house of the 18th century. This archeological discovery confirms documentary hints that Amelung's enterprise was an elaborate one. The project has thus become one of the most important in industrial site archeology thus far undertaken in this country.

C. Malcolm Watkins, curator of cultural history, worked with Joan Pearson Watkins, research collaborator, in recording by film and tape the still living tradition of potterymaking practiced in Moore County, N.C., since the second half of the 18th century. A photographic record of all the processes used there in making a pot, from digging the clay to firing the vessel, as well as tape-recorded interviews with the area's leading potter, were made this year.

Cynthia Adams Hoover, associate curator in charge of musical instruments, completed a paper on "The Slide Trumpet of the 19th Century."

Carl Scheele, associate curator of philately and postal history, completed an article which surveys the history of the division and traces the development of its new exhibits.

At the beginning of the year, Dr. V. Clain-Stefanelli, curator of numismatics, and Mrs. E. Clain-Stefanelli, associate curator, were in Israel at the invitation of the Israeli Government. Dr. Stefanelli traveled also in Greece, the Netherlands, Belgium, Germany, and England, undertaking research on ancient, as well as United States, coins in museums and private collections, and studying the history of coining techniques. Mrs. Stefanelli studied ancient Greek coinage of Messana at the British Museum, the Ashmolean Museum in Oxford, the Fitzwilliam Museum in Cambridge, and the Penningkabinet in The Hague.

Dr. Stefanelli completed research concerning a mission from Peru to procure in Philadelphia modern equipment for the Lima mint, and

the striking in 1855, at the United States mint, of pattern coins for Peru. Mrs. Stefanelli prepared for publication a select numismatic bibliography comprising about 5,000 entries arranged in a topical order.

In July and August, chairman of the department of Armed Forces history Mendel L. Peterson, and museum specialist Alan B. Albright, investigated two underwater sites in Bermuda through the cooperation of E. B. Tucker of the Government of Bermuda. At the close of the year Mr. Peterson was preparing for another diving season. He finished work on a preliminary report on the marking and decoration of muzzle-loading cannon.

Philip K. Lundeberg, curator of naval history, was awarded the Moncado Prize of the American Military Institute for his publication on "The German Naval Critique of the U-Boat Campaign, 1915–1918."

Melvin H. Jackson, associate curator of naval history, in cooperation with Howard I. Chapelle, completed a revision of plans of the schooner *Prince de Neufchatel* preparatory to the construction of a model of that handsome privateer. Dr. Jackson also completed a reassessment of the battle of Negro Head in 1814, involving Revenue cutter *Eagle*, H.M. sloop *Dispatch*, and H.M. frigate *Narcissus*.

Alan B. Albright, museum specialist, completed a paper on the preservation of organic materials recovered from underwater sites.

EXHIBITIONS

A significant milestone in the history of the exhibits program at the Smithsonian Institution was passed when the equivalent of 10 exhibit halls on the first and second floors of the Museum of History and Technology were presented to the public on January 23, 1964. These exhibition areas, totaling more than 75,000 square feet of attractive and instructive displays, include the Flag Hall, First Ladies Hall, and the halls of Everyday Life in the American Past, American Costume, Farm Machinery, Light Machinery, Tools, Vehicles, Railroads, a portion of Heavy Machinery, the Greenough statue of George Washington flanked by eight cases of outstanding national treasures, the centrally located Foucault pendulum, and a temporary exhibition which presents examples of exhibits to be installed in other halls of the museum. This achievement was made possible through nearly 8 years of advanced planning, design of exhibition halls, and design and production of individual displays, some of which had been placed on temporary exhibition in the Arts and Industries Building prior to their installation in the new museum. It could not have been accomplished without the contribution of knowledge and of talent by many individuals on the curatorial staff, the Office of Exhibits, the Buildings Management Division, and private contractors.

Colorful new exhibits of objects from the Near East, Japan, Korea, China, and North and West Africa were first placed on public view when the west portion of the Hall of the Cultures of Asia and Africa was informally opened in late June. Among the exhibits interpreting the traditional cultures of the Asiatic peoples are a life-size group portraying an episode from a Chinese opera, with accompanying push-button sound recording, a display of objects illustrating the evolution of farming in Japan, and a unit on the daily and religious life in Tibet. The Republic of Korea has lent one of its national art treasures, a cast-iron figure of Buddha from the Koryo dynasty (A.D. 935–1392), which is presented in a temple setting with a paneled screen of red silk brocade. North and West African cultures present many striking works of art from peoples whose accomplishments have had a profound influence upon modern art in Europe and America. One of the most dramatic displays is a diorama portraying the smelting of iron ore in primitive furnaces and the fashioning of iron tools by tribesmen from the Mandara Mountain region of the Northern Camaroons. This miniature group was created by exhibits specialists John Weaver, Robert Caffrey, and Peter De Anna. The exhibits in this hall were planned by associate curators of ethnology Gordon R. Gibson and Eugene Knez. The hall layout was made by exhibits designer Dorothy Guthrie and the graphic design of individual units was executed by exhibits designer Lucius Lomax.

The completely renovated life-size group portraying quarrying operations and making of stone artifacts by Indians some 500 years ago at the Piney Branch site, within the present boundaries of the District of Columbia, was opened to the public in the Hall of North American Archeology. Another life-group illustrating Indian copper mining in present Michigan was nearing completion at year's end. Contract construction in the new Hall of Classical Archeology was virtually completed at year's end; the hall was designed by exhibits designer Rolland O. Hower under the scientific supervision of associate curator Gus Van Beek.

The construction contractor's work in the new Hall of Physical Anthropology also was nearing completion at the end of June. About half of the exhibit units for this hall have been completed by exhibits designer Joseph Shannon, who also served as architectural designer for the hall. The contents of the exhibits have been specified by T. Dale Stewart, director of the Museum of Natural History, and Lawrence Angel, curator-in-charge of the Division of Physical Anthropology.

During the spring of 1964, Dr. Knez supervised the exhibits installation of 41 outstanding examples of Chinese, Buddhist, and Hindu stone sculpture, bronze, and other items from China, India, Cambodia,

and Java, which were received from the Alien Property Office of the Department of Justice. Dr. Van Beek worked with the Department of State and the Smithsonian Institution Traveling Exhibition Service on arrangements for loan of the Dead Sea Scrolls and associated materials from the Government of Jordan. In May, during an overseas detail, he conferred with officials of the Jordanian Government, the United States Embassy, and the Palestine Archeological Museum and selected specimens and photographs for use in the exhibition, which is scheduled to be opened in the Museum of Natural History in March 1965. Thereafter it will circulate for 6 months among other museums in the United States under the Smithsonian Institution Traveling Exhibition Service.

At the end of June the exhibits in the east of the half of the Hall of Osteology, comprising the sections on mammals and birds, were informally opened to the public. The skeletons in this exhibition range in size from one of the gray whale to those of small birds. Skeletal materials are supplemented by graphic portrayals of the appearance of the particular examples displayed in the flesh. Among the many interesting displays in the mammal section is one comparing the skeleton of man with those of other Primates. In the section on birds a unit points out the bony structure differences which serve as bases for scientific classification of birds. The sections of this hall devoted to reptiles, amphibians, and fishes are in process of preparation and installation. Planning of the exhibits in this hall has been coordinated by David H. Johnson, curator-in-charge of the division of mammals, with the cooperation of the staff members of all the divisions of this department. Hall design was by Anthony Di Stefano and graphic design by exhibits designer Morris M. Pearson.

On February 19, 1964, a temporary exhibition entitled "Return to the Sea" was opened on the mezzanine of the Hall of Life in the Sea. This display, a joint effort of the federal Interagency Committee of Oceanography and the Smithsonian Institution, has as its theme the renewal of interest in oceanography and the marine environment.

Associate curator Charles Cutress and Kjell Sandved spent approximately 2 months at Honolulu, Hawaii, Dillon Beach, Calif., and Friday Harbor, Wash., obtaining photographs and well-preserved specimens of animals of which models will be made for display in additional permanent exhibits in this hall.

Preparation of models and the securing of specimens for the Hall of Cold-blooded Vertebrates (fishes, amphibians, and reptiles) was continued during the year. Leonard P. Schultz, curator-in-charge of the division of fishes, who is coordinating the planning of exhibits for this hall, and Alfred Strohlein spent several days in the vicinity of Seattle, Wash., during October collecting red salmon and background ma-

terials for the group on salmon spawning. Exhibits designer Barbara Craig prepared the architectural layout for this hall. Graphic design is by Joseph Shannon.

Planning for the Hall of Plant Life in the Museum of Natural History has continued at an accelerated rate since January 1964. At that time a planning committee was established consisting of Assistant Director R. S. Cowan, chairman, and curators M. E. Hale, Jr., T. R. Soderstrom, Stanwyn G. Shetler, Dan Nicolson, and Richard H. Eyde. This group met regularly with exhibits designer Rolland O. Hower to develop specific plans for the construction of exhibits. Preliminary statements of the intent and content of each unit are in preparation and a study model of a proposed organization of exhibits in this large hall was prepared by Mr. Hower. In the late spring three members of the committee visited localities in the eastern part of the United States to select study sites in which to obtain data for construction of some of the habitat groups. Preparation of botanical models for use in the exhibits in this hall was in progress in the exhibits laboratory.

Planning and design of the new physical geology and meteorite exhibits were completed in preparation for the beginning of construction in this area in the summer of 1964. Additional space for the gem exhibits will be provided in the same construction project. The physical geology exhibit will interpret the nature and properties of materials composing the earth, the distribution of materials throughout the globe, the processes by which they are formed, altered, transported, and distorted, and the nature and development of the landscape. The new hall has been planned by curator-in-charge of the division of mineralogy and petrology, George S. Switzer, and associate curators Paul E. Desautels and Edward P. Henderson. The hall layout has been prepared by exhibits designers Dorothy Guthrie and Barbara Craig.

The fourth and last of the remarkable series of mural paintings in the Hall of the Age of Mammals in North America, representing a Pliocene mammalian assemblage was completed in June by the artist Jay H. Matternes.

Associate curator Clayton E. Ray initiated preliminary planning of displays in the hall to be devoted to life of the Pleistocene, the geologic epoch immediately preceding the present, in consultations with members of the exhibit staff. Much of the time of the paleontological laboratory staff was devoted to repairing and remounting skeletons of the various larger Pleistocene mammals that were previously exhibited and in restoring new skeletal remains for presentation in this hall.

Four halls of the Department of Science and Technology in the east

portion of the first floor were opened in January when the Museum of History and Technology was opened to the public.

The Railroad Hall interprets the history of street railways, as well as railroads, through a few choice full-scale vehicles and an extended series of accurately and precisely executed scale models. The giant 280-ton Pacific-type steam locomotive No. 1401, largest and one of the most impressive 3-dimensional specimens in the museum, stands near the row of east windows through which it may be viewed from outside of the building at night, as well as by daylight. A cut-away scale model of a Diesel-electric locomotive shows a type that has supplanted the steam locomotive on American railroads in recent years. A full-size cable car used in Seattle, Wash., at the turn of the century stands on a section of narrow-gauge track in an elevated position so that visitors can see the underground construction required for its operation. Basic developments in street cars, locomotives, and railroad cars are illustrated by nearly 80 models, most of them built to the same scale. The hall was planned by associate curator John H. White, Jr., in collaboration with exhibits designers James Mahoney, Virginia Mahoney, and Deborah Bretzfelder.

The adjacent Vehicle Hall traces the development of various types of road vehicles in the United States from the 18th century to the present day. Among the outstanding horse-drawn vehicles on display are two variations of the famous stagecoach, widely used in the East and West beyond the lines of the early railroads; the finely constructed Lawrence family coach built in 1851; a city omnibus built by E. M. Miller of Quincy, Ill. The automobiles illustrate the rapid evolution of automobile design and manufacture from the 1890's. Along with the Balzer and Haynes motor wagons appear the famous Winton mile-a-minute racer of 1902, the Winton in which Dr. H. Nelson Jackson drove the first transcontinental motor trip in 1903, and a sturdy Mack Bulldog truck. One of the very rare Draisines, known also as a hobby horse, is shown in the cycle collection. Museum Specialist Donald Berkebile planned the exhibits in this hall with assistance in layout from exhibits designer Riddick Vann.

The Hall of Tools illustrates the history and development of machine tools. Introductory exhibits display hand tools with which men performed laboriously the same tasks as were later accomplished with much greater speed and precision by machine. A short sound film in color describes the five basic machining operations—planing, milling, drilling and boring, turning, and grinding. The attainment of greater precision in measurement, important to the development of machine tools, is emphasized in a series of exhibits tracing the history of measurement from the Roman cubit to modern times. An outstanding feature of this hall is a reconstructed full-size machine

shop of about 1855 equipped with some of the oldest machine tools in the collection. Silvio Bedini, curator-in-charge of the division of mechanical and civil engineering, and his predecessor, Eugene S. Ferguson, selected the machines and planned the case exhibits in this hall with the cooperation of exhibits designers Bright Springman, Harry Hart, and John Clendening. William Henson installed the machines and placed them in operating condition.

A major portion of the Hall of Light Machinery illustrates the evolution of timekeeping. The introductory exhibit, through a revolving globe bearing small sundials on its surface, demonstrates the basic importance of the daily cycle of the earth's rotation as the foundation of man's timekeeping systems. The series of timekeeping exhibits illustrates the gradual developments from early sundials, sandglasses, and waterclocks to the most precise modern electronic clocks. In the center of the hall is a reconstruction of a Renaissance clock tower, the four sides of which will display a sun dial and civil, astronomical, and automation dials actuated by an American tower clock of 1786. Both the sun dial and civil time dials have been installed, the former by museum specialist Dorothy Briggs and the latter by its maker, Thwaites & Reed of London, England. The exhibits in other sections of this hall show machines derived from the skills developed by clock and instrument makers. One series traces the development of the phonograph from Thomas Edison's original invention through the work of Alexander Graham Bell's Volta Laboratory and the more recent talking machines. Exhibits on the evolution of the typewriter include early original machines and patent models. Exhibits in this hall were planned by associate curator Edwin A. Battison in cooperation with hall designer Bright Springman and exhibits designer Barbara Bowes.

At the close of the year installation of exhibits in the Hall of Civil Engineering was nearing completion. This hall interprets the story of bridge- and tunnel-building through the ages. It shows how the use of new materials enabled bridge builders to construct longer spans and illustrates through scale models many of the classic bridges of history. The tunnels section features a series of cut-away scale models illustrating the development of methods in both soft-ground and hard rock tunneling and depicting men at work constructing some of the major tunnels in which new drilling methods and mechanisms were employed. Associate curator Robert M. Vogel prepared the technical specifications for this hall. Exhibits layout and design are the work of exhibits designers John Brown and Harry Hart.

Considerable progress also was made in the design, production, and installation of exhibits in the Hall of Heavy Machinery. Exhibits interpreting the early development of the steam engine—including a

reconstruction of the Watt engine—were opened to the public in January. It is planned to open the series of exhibits on refrigeration and the Diesel engine when the adjoining Civil Engineering Hall is opened in July 1964. Robert M. Vogel is responsible for planning this hall's contents. The layout and units designs have been prepared by exhibits designer Harry Hart.

A considerable number of the scale models of historic types of vessels from the museum's outstanding watercraft collection have been placed in free-standing exhibition cases in the American Merchant Shipping Hall by exhibits specialists James A. Knowles, Jr., under the supervision of Howard I. Chapelle, curator-in-charge of the division of transportation.

A temporary exhibition of communications satellites is being installed in the Hall of Electricity; as a nucleus for this exhibit the back-up satellite for *Telstar I*—presented to the museum on July 10, 1963, the first anniversary of its launching—will be on view. Installation of cases for permanent exhibits which will interpret current-electricity, was nearing completion at year's end. These exhibits have been planned by Bernard S. Finn, associate curator in charge of the division of electricity. Exhibits designer Nadya Kayloff has nearly completed the design on these displays.

In the Halls of Pharmacy, Medicine, and Dentistry installation neared completion of an 1890-period drugstore, of period interiors depicting a portion of a room in the Massachusetts General Hospital, and a midwestern dentist's office. The Old World Apothecary Shop, formerly on view in the Arts and Industries Building, has been moved and is being installed in the new Hall of Pharmacy. Two new exhibits destined for exhibition in the new museum were placed on temporary display in the Arts and Industries Building. One depicts in diorama form Dr. Philip S. Physick removing a large paratoid gland tumor in the circular room of the Pennsylvania Hospital in 1805, long before the discovery of anesthesia. The other is an enlarged model of the human ear donated by the Lambert Institute of Otalogy of New York City. Dr. Sami K. Hamarneh, curator-in-charge of medical sciences, assisted by Dr. Alfred R. Henderson, consultant, are completing exhibit plans for the medical science exhibits, in cooperation with John Clendening, exhibits designer.

The Foucault pendulum, prepared by the California Institute of Technology and exhibited in the central rotunda of the new museum, has fascinated visitors since the opening of the building. The division of physical sciences, placed in charge of this exhibit, has been making careful studies of its operation and of the problem of interpreting it to the public. A large graphic explanation has been planned by Dr. Walter F. Cannon, curator-in-charge of the division,

which is being produced by the exhibits laboratory. Development of exhibits for the Hall of Physical Sciences progressed with the completion of a layout plan for the mathematics section and the production of all but one unit in the section on astronomy.

The Farm Machinery Hall was on view when the new Museum of History and Technology building opened in January. Through displays of original objects and accurate scale models this hall shows how the invention and use of labor-saving machines played a major role in the rapid expansion of American agriculture since the early 19th century. The earlier hand-wielded and horse-drawn implements are contrasted with later self-propelled machines which performed the same basic tasks of plowing, planting, cultivating, and harvesting food crops. Thomas Jefferson's plan for a more efficient moldboard which any farmer of his time could make with his own tools and fit to his plow is a feature display in the series on the development of the plow. John Deere's "steel" plow is shown, as are scale models of the McCormick and Hussey reapers of the 1830's. Colorful portable steam engines which supplied belted power to the old threshers and other farm machines are displayed along with gasoline and diesel tractors which pulled and powered large farm implements. The exhibits in this hall were planned by associate curator Edward C. Kendall in cooperation with exhibits designer Riddick Vann. The human figures which help to establish scale and add interest to the miniature models of reapers were executed by exhibits technician Susan Wallace.

Installation of exhibits in the new Hall of Graphic Arts was begun in the spring of 1964 in anticipation of a fall opening. This hall will explain the processes and present outstanding examples of graphic works created and produced by hand and by photomechanical processes. These exhibits have been planned by curator-in-charge Jacob Kainen and associate curator Fuller O. Griffith of the division of graphic arts in cooperation with exhibits designer Nadya Kayaloff.

Among the displays in the preview of future exhibits in the temporary exhibits gallery on the first floor of the new museum are a number of outstanding objects from the collections of this department, including the Benjamin Franklin Press, the Kelmscott Chaucer, three prints of old masters, and an early American handloom, built by a pioneer settler of western Pennsylvania about 1800. The loom was prepared for weaving and is used for weekly demonstrations by associate curator of textiles Rita Adrosko.

Miss Bowman, Mrs. Lois Vann, and Miss Maureen Collins of the division of textiles assisted in preparing the backing of the Star-Spangled Banner prior to its installation in the new museum. Miss Collins also assisted Mrs. Murray in the preparation of specimens for exhibition in the Hall of American Costume. Several textiles speci-

mens were loaned to the American Museum in Britain, at Claverton Manor near Bath, England.

A reproduction of the figure 8 stellerator developed by Dr. Lyman Spitzer of Princeton University was placed on exhibition in the west window area on the first floor of the new museum shortly before the building was opened to the public. It is symbolic of the research involving the generation of temperatures in excess of 100 million degrees Centigrade.

Three of the four halls of the Department of Civil History were on public view when the new museum opened in January. The fourth, the Hall of Historic Americans, was formally opened to the public in June.

The Hall of Everyday Life in the American Past, comprising the largest exhibition gallery in the museum, displays the material evidences of domestic life in America before 1900. The furnishings, utensils, decorative arts, and other objects illustrating aspects of the cultural life of the country are presented in a series of cases, period rooms, and platform groupings progressing chronologically from an initial series of displays devoted to the European backgrounds of early settlement groups. Among the outstanding exhibits are a reproduction of a room from an 18th-century Spanish New Mexican adobe home and objects of religious art from the Franciscan missions of the Southwest; displays ranging from artifacts obtained archeologically to fine furniture, pewter, and silver of the English colonies of the eastern seaboard, and an entire log house from Mill Creek Hundred, Del., dating from about 1740 showing both the exterior and interior construction and the furnishings of this home. This hall was planned and installed under the direction of C. Malcolm Watkins, curator-in-charge, assisted by associate curators Rodris Roth and John N. Pearce of the division of cultural history. It was designed by John E. Anglim, exhibits chief, with the assistance of exhibits designer Deborah Bretzfelder. Period rooms and the log house were executed by George H. Watson and his staff of restoration specialists with the professional assistance of Mrs. E. Boyd, curator of Spanish Colonial art, Museum of New Mexico, and architects Robert L. Raley of Newark, Del., and Robert E. Plettenberg of Santa Fe, N. Mex.

The new First Ladies Hall provides a more appealing medium for continuing the Smithsonian Institution's tradition of exhibiting the dresses worn by the wife or official hostess of each President of the United States. These dresses show the changes in American costume from the 18th-century style worn by Martha Washington to the simple lines and elegant fabrics of more recent First Ladies. The dresses are displayed upon mannequins in a series of eight room settings, each appropriately finished and furnished to indicate the periods and en-

vironments in which the dresses are worn. Two rooms reproduce those in the house at 190 High Street in Philadelphia where President and Mrs. Washington lived before the White House was built and display furniture and fixtures owned and used by them. The other room settings combine architectural details from the White House, including four original White House mantels and the 1902 paneling from the East Room, with furniture and accessories used both in the White House and in Presidential family homes. This hall was developed by associate curator Margaret Brown Klapthor in cooperation with exhibits chief Benjamin W. Lawless.

The new Hall of American Costume adequately presents for the first time the Museum's rich and extensive collection of men's, women's, and children's clothing of the 18th, 19th, and 20th centuries. It includes accessories of dress such as shoes, hats, handkerchiefs, parasols, and gloves and such decorative accessories as fans, embroidered and beaded purses, and many fine examples of period jewelry. Many of the clothing items are exhibited on mannequins which portray the hair dress appropriate to the costumes, and some are shown in groupings in partial room settings. Illustration of various types of clothing selected from paintings and engravings dealing with the history of costume supplements the original specimens on display. The entire hall has been one of great interest for historians, artists, and students of American style and taste. The exhibits were planned and installed under the direction of assistant curator Anne W. Murray. Hall design was by exhibits designer Robert M. Widder; graphic design by exhibits designers Judith Borgogni, Virginia Mahoney, and Deborah Bretzfelder.

The Hall of Historic Americans is unlike other museum presentations in the United States. A portion of the hall is devoted to a capsule history of American political campaign techniques, tracing their development from the era of genteel "parlor politics" to the modern political use of the mass media of communications. A dramatic political parade illustrates the development of Presidential campaigning between 1840 and 1930 with papier mâché marchers carrying authenic political banners, pennants, and torchlights and wearing campaign clothing and badges. An adjoining area, illustrating the important relationship between politics and the press, radio, and television, includes microphones used by Franklin D. Roosevelt in delivering his historic fireside chats on radio and by Dwight D. Eisenhower in television broadcasts. Several exhibits display memorabilia of distinguished families and individuals—the Washington and Adams families, Ulysses S. Grant, and Abraham Lincoln. In one of these a newly sculptured figure of Abraham Lincoln wearing the business suit which he wore on the day of his assassination, stands

in a setting which closely resembles that shown in several Mathew Brady photographs of the President. Planning and installation of the exhibits in this hall were under the direction of curator-in-charge Wilcomb E. Washburn, assisted by associate curator Keith E. Melder and assistant curator Herbert R. Collins of the division of political history in association with exhibits designer Robert Widder. At the formal ceremonies opening the hall on the evening of June 29, featured speakers included the Honorable Frances P. Bolton, Member of the House of Representatives from Ohio, and the Honorable Claiborne Pell, United States Senator from Rhode Island.

Marked progress was made in the preparation of the Hall of Philately and Postal History. During March several examples of stamp production equipment were transported to the Museum and moved into position in the stamp production alcove of this hall by the Bureau of Printing and Engraving. The series of exhibits on the history of the world's posts were produced, exhibit cases for models of vehicles used to transport the mails and for postage meter and canceling machines were delivered to the hall, and the refinishing of the pull-out frames which will exhibit by country and systematic National Postage Stamp Collection was completed. This hall has been planned by curator Carl H. Scheele with the assistance of museum technician Francis E. Welch in collaboration with exhibits designer John Clendening.

Associate curator of numismatics Elvira Clain-Stefanelli with the assistance of the Medallic Art Co. and the United States Mint prepared a display of contemporary United States medals for the Museum's Hall of Monetary History and Medallic Art. A temporary display illustrating the history of the traveler's check, including James C. Fargo's announcement of 1891 initiating the issuance of traveler's checks by the American Express Co., was installed in February. On March 27 a special exhibition of original mint models and designs for the John F. Kennedy half dollar was placed on display through the good offices of the Director of the Mint, Miss Eva Adams, and the Superintendent of the Philadelphia Mint, Michael H. Sura. In April a large display of the currencies of the Austrian Empire was installed, employing material recently received from the Mortimer and Anna Neinken Collection.

The Star-Spangled Banner, the original flag which flew over Fort McHenry at Baltimore during the attack of the British fleet on September 13–14, 1814, and which inspired Francis Scott Key to write the words of what is now our National Anthem, was installed in the new Museum of History and Technology when it was opened to the public in January. Although this most important museum object related to the history of the United States had been exhibited in the Arts and

Industries Building since it was presented to the Smithsonian Institution in 1912, it is now displayed for the first time at full length, undraped, and in a place of honor befitting its importance as a national symbol. The flag is displayed over a supporting fabric large enough to indicate its original dimensions of 30 by 42 feet and completely covers a specially designed metal grid which holds the flag and its supporting fabric in a vertical position and hangs in an atmosphere of filtered air carefully controlled for the proper temperature and humidity. The flag was prepared for exhibition and installed under the direction of Edgar M. Howell, curator-in-charge of the division of military history, with the assistance of Grace Rogers Cooper, curator-in-charge, division of textiles. The setting for the flag was designed by Walker Cain of the firm of Steinmann, Cain & White, architects for the new Museum. The cased exhibit was designed by Robert Widder, exhibits designer.

The entire professional staff of the department has been deeply concerned with the development of exhibits for the Armed Forces history halls in the new Museum. The exhibit of Armed Forces history in the Arts and Industries Building will remain until the early fall of 1964.

Assistant director John C. Ewers coordinated the varied exhibits activities of the Museum of History and Technology, with the able assistance of John N. Edy who planned the physical movement of materials. Benjamin W. Lawless continued to supervise the design, production, and installation of exhibits, aided by Robert Widder in design, Bela S. Bory and William Clark in production, Robert Klinger in the model shop, Stanley Santoroski in supervision of installation, and Carroll Lusk, lighting specialist. Editing of the curators' drafts of exhibits scripts was continued by George Weiner, assisted by Constance Minkin and Edna Wright. The timely assistance of buildings manager Andrew F. Michaels and his staff contributed substantially to the success of this program, as did the services of John E. Cudd, liaison architect, and George Watson, skilled specialist in the renovation and installation of period interiors.

John E. Anglim, exhibits chief, continued in charge of the planning and preparation of all exhibits and directly supervised the operation of the exhibits laboratory in the Natural History Building, with the assistance of Gilbert Wright. Julius Tretick supervised the production and installation of natural history exhibits. Substantial portions of the Hall of the Cultures of Asia and Africa and the Hall of Osteology in the Museum of Natural History were opened to the public in June and progress was made on hall layout and/or exhibits design in five other galleries in that building. Director T. Dale Stewart continued to serve as chairman of the committee coordinating the

exhibits modernization program in natural history, and assistant director Richard S. Cowan was responsible for integrating the work of curators and exhibits personnel in the development of natural-history exhibits.

DOCENT SERVICE

The Junior League of Washington conducted its volunteer guide program for the school classes of the greater Washington area through the Smithsonian museums for the tenth consecutive year. The program was carried out through the cooperation of G. Carroll Lindsay, curator of the Smithsonian Museum Service, with Mrs. Dickson R. Loos as chairman of the League's guide service and Mrs. Arnold B. McKinnon as cochairman. Mrs. McKinnon will serve as chairman for the forthcoming year with Mrs. Joseph Smith, Jr., as cochairman.

During the 1963–64 school year 20,044 children were conducted on 701 tours. During the year, the 100,000th child to participate in the program was conducted on a tour by the volunteers.

Tours were conducted in the Halls of Mammals, Native Peoples of the Americas, and Textiles for grades 3 through 6; and in the Halls of Gems and Minerals and Prehistoric Life for grades 5 through junior high. The Prehistoric Life tour was given for the first time this year. The Power Hall, in which tours had been conducted for the past 6 years, was closed to tours because of its move to the Museum of History and Technology. Since the beginning of Power Hall tours in 1958, about 12,000 children have been conducted through this hall.

Tours were offered 5 days a week, four tours each day, every half hour beginning at 10:00 a.m. through 11:30 a.m. in the Halls of Mammals and Native Peoples of the Americas. Tours in the Halls of Gems and Minerals and Prehistoric Life were offered Monday through Friday at 10:00 a.m. and 11:00 a.m. The textile tour was offered only on Wednesdays and Fridays at 10:00 a.m. and 11:00 a.m.

Tours were conducted from October 2 through May 29, with the exception of the month of April 1964, when, as usual, tours were suspended because of the exceedingly heavy visitor traffic in all museum halls during the Easter and cherry-blossom seasons. During May, for the first time, the volunteers made use of compact, portable amplifiers. With the aid of these amplifiers it is possible to conduct tours even when the exhibit halls are heavily crowded.

In addition to Mrs. Loos and Mrs. McKinnon, the members of the League's guided tour committee were:

Mrs. Timothy Atkeson, Mrs. Leon Bernstein, Mrs. Thomas A. Bradford, Jr., Mrs. Challen E. Caskie, Mrs. Thomas R. Cate, Mrs. F. David Clarke, Mrs. Steven Conger, Mrs. Henry M. deButts, Mrs. Lee M. Folger, Mrs. Rockwood Foster, Mrs. George Gerber, Mrs. Gilbert Grosvenor, Mrs. James Harvey, Mrs. William

Henry, Mrs. Walter M. Johnson, Jr., Mrs. Vernon Knight, Mrs. Lansing Lamont, Mrs. Edward Leonard, Mrs. John Manfuso, Jr., Mrs. H. Roemer McPhee, Mrs. R. Kendall Nottingham, Mrs. L. Edgar Prina, Mrs. W. James Sears, Mrs. Walter Slowinski, Mrs. Joseph Smith, Jr., Mrs. James H. Stallings, Jr., Mrs. Edwin F. Stetson, Mrs. E. Tilman Stirling, Mrs. John S. Vorhees, Mrs. Richard Wallis, and Mrs. Mark White.

The Institution deeply appreciates the able and devoted efforts of these volunteers, whose services to the schools of the Washington area encourage effective use of Smithsonian museum exhibits by teachers and students.

BUILDINGS AND EQUIPMENT

The contract for the construction of the west wing of the Natural History Building, including the last stage of renovation of the original building, was signed in August 1963. Excavation for the wing was begun in November and, owing to a mild winter, the foundations were laid and the superstructure erected at a rapid rate. By the end of the fiscal year most of the granite facing was in place.

Within the original building a large L-shaped area in the northwest corner of the third floor was cleared for renovation by October. Work in this area proceeded slowly, owing to the need for preliminary installation of electrical conduits. This area was still not finished by the end of the fiscal year, but work was proceeding at a faster pace.

The General Services Administration accepted all remaining areas and systems of the Museum of History and Technology, not previously accepted, effective August 30, 1963, with certain exceptions.

President Lyndon B. Johnson dedicated the building at ceremonies held in the evening of January 22, 1964. The Museum was opened to the public at 9:00 a.m., January 23, 1964. The Museum has been visited by record-breaking crowds and has become the focus of the attention of scholars, university departments, and museum professionals, who are interested by the impact which the scholarly staff and great collections of the Smithsonian can have on education at all levels from the elementary student to the postgraduate.

CHANGES IN ORGANIZATION AND STAFF

Approval for the establishment of a Department of Entomology was given by former Secretary Leonard Carmichael on April 30, 1963. Accordingly, on July 1, 1963, the division of insects was separated from the Department of Zoology and became the Department of Entomolgy. The five divisions in the department are: Neuropteroids, Lepidoptera, Coleoptera, Myriapoda and Arachnida, and Hemiptera.[2]

[2] For administrative purposes, and until new divisions are established in the new Department of Entomology, the newly created units will deal with subject matters not necessarily closely related; the division of neuropteroids will handle administrative matters pertaining to the Orthoptera and Isoptera; the division of Lepidoptera will handle Diptera; the division of Hemiptera will process transactions involving Hymenoptera.

Likewise, a plan to divide the Department of Geology into two departments, Mineral Sciences and Paleobiology, was approved on August 20, 1963, and the reorganization became effective on October 15, 1963. The diversity of disciplines in the old geology department made the partition logical and desirable. The purely physical subjects of mineralogy, petrology, and meteoritics are now separated from the biological subjects of paleontology and ecology. The Department of Mineral Sciences consists of three divisions, Mineralogy, Meteorites, and Petrology. The Department of Paleobiology consists of four divisions: Invertebrate Paleontology, Vertebrate Paleontology, Paleobotany, and Sedimentology.

By direction of the Secretary, a new system was inaugurated in May whereby certain administrative duties within the Museum are rotated in order to free senior staff members for research and publication, permitting others to participate more widely in administration. While it is believed that it is at the department level that such moves are most needed, the designation of more than one full curator within a division will make it possible to rotate appointments in the divisions as well. This will be done by detailing a member of the division curatorial staff to serve as "curator in charge." The curator formerly in charge of that division will either become a senior scientist or historian or continue on the personnel rolls as a full curator. Such rotations may be scheduled by museum directors in response to recognized needs, although they will not become a matter of set schedule or routine. The title "head curator" has accordingly been discontinued, and the title for the administrative head of each department will be "chairman." The former chairman of a department may be appointed a senior scientist or continue to serve as a full curator, upon the recommendation of his Museum director.

During fiscal year 1964 the following appointments were made to the scientific staff of the Museum of Natural History: Dr. Wallace R. Ernst, associate curator of phanerogams, on July 29, 1963; David B. Lellinger, associate curator of ferns, on August 26, 1963; Dr. Richard C. Froeschner, associate curator in charge of Hemiptera, on August 26, 1963; Dr. Richard L. Zusi, associate curator of birds, on September 3, 1963; Dr. Richard B. Woodbury, associate curator of archeology, on December 15, 1963; Dr. Clayton E. Ray, associate curator of vertebrate paleontology, on December 18, 1963; Dr. Dan H. Nicolson, associate curator of phanerogams, on January 5, 1964; Dr. David L. Pawson, associate curator of marine invertebrates, on May 20, 1964; Dr. Walter H. Adey, associate curator of paleobotany, on June 30, 1964; and Dr. Richard H. Benson, associate curator of invertebrate palentology, on June 30, 1964.

Among the additions to the staff of the Museum of History and

Technology were the appointments of Miss Deborah J. Mills, assistant curator in the chairman's office, Department of Science and Technology, on July 16, 1963; Miss Rita J. Adrosko, associate curator in the division of textiles, Department of Arts and Manufactures, on August 4, 1963; Miss Anne Castrodale, assistant curator, growth of the United States, Department of Civil History, on September 29, 1963; and Miss Uta C. Merzbach, associate curator, division of physical sciences, Department of Science and Technology, on October 28, 1963.

Mrs. Agnes Chase, world-famous agrostologist and Smithsonian honorary research associate, died on September 24, 1963.

Francis J. McCall, curator of the division of philately and postal history, died on July 20, 1963. He had headed the division since November 6, 1962, and had just begun to see the results of some of the fine programs he had inaugurated.

Miss Ellen Joy Finnegan, assistant curator in the section of growth of the United States, left the Museum of History and Technology on August 14, 1963, to accept a teaching position in Thailand. Junior curator Barbara F. Bode resigned from the numismatics division on September 20, 1963, and Anthony W. Hathaway, assistant curator in the division of cultural history, resigned on June 23, 1964.

Mrs. Jacqueline S. Olin became the research chemist to assist the conservator-in-charge of the conservation research laboratory on June 21, 1964.

Bela S. Bory, production supervisor of the Museum of History and Technology exhibits laboratory, accepted another governmental position and left the office of exhibits on June 27, 1964.

Respectfully submitted.

Frank A. Taylor, *Director.*

S. Dillon Ripley,
Secretary, Smithsonian Institution.

Report on the International Exchange Service

Sir: I have the honor to submit the following report on the activities of the International Exchange Service for the fiscal year ended June 30, 1964:

The original plan of organization of the Smithsonian Institution presented to the Board of Regents by Joseph Henry in 1847 provided for a system of exchange of current publications which would afford the Smithsonian Institution the most ready means of entering into friendly relations and correspondence with all the learned societies in the world and of enriching the Smithsonian library with the current transactions and proceedings of foreign institutions.

When the first of the Smithsonian's long series of scientific publications, *Ancient Monuments of the Mississippi Valley*, was issued, copies were sent to scientific and learned institutions abroad. In return, the Smithsonian Institution received many valuable publications from foreign institutions. To continue this desirable international exchange of scientific information, the Smithsonian Institution appointed agents in a number of foreign countries to distribute the publications received from the Smithsonian Institution and to forward to the Smithsonian Institution the publications received from the foreign institutions.

In 1851 the privilege of transmitting scientific, cultural, and literary publications through the Smithsonian Institution to other countries, and of receiving similar publications from foreign institutions in return, was extended to Government agencies and a number of scientific societies in the United States. This opportunity to distribute their publications abroad was eagerly accepted and the system grew so rapidly that today most Government agencies, many universities, and scientific organizations representing every State in the Union utilize the International Exchange Service. The International Exchange Service functions as a medium for developing and executing in part the broad and comprehensive objective of the Smithsonian Institution—"the increase and diffusion of knowledge among men." This service has grown from a few hundred packages of publications transmitted per year to more than a million packages during the past fiscal year.

Publications weighing 891,148 pounds were received during the year from Government bureaus and departments, congressional committees, members of Congress, universities, agricultural experiment stations, learned societies, scientific organizations, and individuals for transmission to addressees in more than 100 different countries. Representative of these publications are the following: *Language, Journal of the Linguistic Society of America; Journal of the National Education Association; Journal of Science; Yale University Bulletin; Yearbook of the Carnegie Institution; Zoologica; Transactions of the American Association of Physicians; Expedition; Brevoria; Oregon Law Review; Museum of Art Register; Paleontological Contributions; Anthropological Record; Novitates; Proceedings of the American Philosophical Society; Contributions of the Scripps Institution of Oceanography;* and *Proceedings of the California Academy of Sciences.*

Publications are accepted for transmission to addressees in all countries except to the mainland of China, North Korea, and Communist-controlled areas of Viet-Nam. Packages of publications from domestic sources intended for addressees in the United States or in a territory subject to the jurisdiction of the United States are not accepted for transmission.

Listed below are the names and addresses of the foreign exchange bureaus to whom the International Exchange Service forwards addressed packages of publications for distribution.

LIST OF EXCHANGE SERVICES

AUSTRIA: Austrian National Library, Vienna.

BELGIUM: Service des Échanges Internationaux, Bibliothèque Royale de Belgique, Bruxelles.

CHINA: National Central Library, Taipei, Taiwan.

CZECHOSLOVAKIA: Bureau of International Exchanges, University Library, Prague.

DENMARK: Institut Danois des Échanges Internationaux, Bibliothèque Royale, Copenhagen.

EGYPT: Government Press, Publications Office, Bulaq, Cairo.

FINLAND: Library of the Scientific Societies, Helsinki.

FRANCE: Service des Échanges Internationaux, Bibliothèque Nationale, Paris.

GERMANY (Eastern): Deutsche Staatsbibliothek, Berlin.

GERMANY (Western): Deutsche Forschungsgemeinschaft, Bad Godesberg.

HUNGARY: Service Hongrois des Échanges Internationaux, Országos Széchenyi Konyvtár, Budapest.

INDIA: Government Printing and Stationery Office, Bombay.

INDONESIA: Minister of Education, Djakarta.

ISRAEL: Jewish National and University Library, Jerusalem.

ITALY: Ufficio degli Scambi Internazionali, Ministero della Pubblica Istruzione, Rome.

JAPAN: Division for Interlibrary Services, National Diet Library, Tokyo.

KOREA: National Central Library, Seoul.[1]

NETHERLANDS: International Exchange Bureau of the Netherlands, Royal Library, The Hague.

NEW SOUTH WALES: Public Library of New South Wales, Sydney.

NEW ZEALAND: General Assembly Library, Wellington.

NORWAY: Service Norvégien des Échanges Internationaux, Bibliothèque de l'Université Royale, Oslo.

PHILIPPINES: Bureau of Public Libraries, Department of Education, Manila.

POLAND: Service Polonais des Echanges Internationaux, Bibliothèque Nationale, Warsaw.

PORTUGAL: Servico Português de Trocas Internacionais, Biblioteca Nacional, Lisbon.

QUEENSLAND: Bureau of International Exchange of Publications, Chief Secretary's Office, Brisbane.

RUMANIA: International Exchange Service, Biblioteca Centrala de Stat, Bucharest.

SOUTH AUSTRALIA: South Australian Government Exchanges Bureau, Government Printing and Stationery Office, Adelaide.

SPAIN: Junta de Intercambio y Adquisición de Libros y Revistas para Bibliotecas Públicas, Ministerio de Educación Nacional, Madrid.

SWEDEN: Kungliga Biblioteket, Stockholm.

SWITZERLAND: Service Suisse des Échanges Internationaux, Bibliothèque Centrale Fédérale, Berne.

TASMANIA: Secretary of the Premier, Hobart.

TURKEY: National Library, Ankara.

UNION OF SOUTH AFRICA: Government Printing and Stationery Office, Cape Town.

UNION OF SOVIET SOCIALIST REPUBLICS: Bureau of Book Exchange, State Lenin Library, Moscow.

VICTORIA: State Library of Victoria, Melbourne.

WESTERN AUSTRALIA: State Library, Perth.

YUGOSLAVIA: Bibliografski Institut FNRJ, Belgrade.

FOREIGN DEPOSITORIES OF GOVERNMENTAL DOCUMENTS

The Smithsonian Institution received during the fiscal year 664,067 publications weighing 250,677 pounds for transmission to the recipients of the full sets of official United States Government publications, and 69,436 publications weighing 45,823 pounds for transmission to the recipients of the partial sets. The recipients of the full sets receive copies of all of the official publications, while the recipients of the partial sets receive a selected list of the official publications.

RECIPIENTS OF THE FULL SETS

ARGENTINA: División Biblioteca, Ministerio de Relaciones Exteriores y Culto, Buenos Aires.

AUSTRALIA: National Library of Australia, Canberra.

- NEW SOUTH WALES: Public Library of New South Wales, Sydney.
- QUEENSLAND: Parliamentary Library, Brisbane.
- SOUTH AUSTRALIA: Public Library of South Australia, Adelaide.
- TASMANIA: Parliamentary Library, Hobart.
- VICTORIA: State Library of Victoria, Melbourne.
- WESTERN AUSTRALIA: State Library, Perth.

[1] Change in name.

AUSTRIA: Administrative Library, Federal Chancellery, Vienna.
BELGIUM: Service Belge des Échanges Internationaux, Bruxelles.
BRAZIL: Biblioteca Nacional, Rio de Janeiro.
BURMA: Government Book Depot, Rangoon.
CANADA: Library of Parliament, Ottawa.
  MANITOBA: Provincial Library, Winnipeg.
  ONTARIO: Legislative Library, Toronto.
  QUEBEC: Library of the Legislature of the Province of Quebec.
  SASKATCHEWAN: Legislative Library, Regina.
CEYLON: Department of Information, Government of Ceylon, Colombo.
CHILE: Biblioteca Nacional, Santiago.
CHINA: National Central Library, Taipei, Taiwan.
  National Chengchi University, Taipei, Taiwan.
COLOMBIA: Biblioteca Nacional, Bogotá.
COSTA RICA: Biblioteca Nacional, San José.
CUBA: Dirección de Organismos Internacionales, Ministerio de Relaciones Exteriores, Habana.
CZECHOSLOVAKIA: University Library, Prague.
DENMARK: Institut Danois des Échanges Internationaux, Copenhagen.
EGYPT: Bureau des Publications, Ministère des Finances, Cairo.
FINLAND: Parliamentary Library, Helsinki.
FRANCE: Bibliothèque Nationale, Paris.
GERMANY: Deutsche Staatsbibliothek, Berlin.
  Free University of Berlin, Berlin-Dahlem.
  Parliamentary Library, Bonn.
GREAT BRITAIN:
  British Museum, London.
  London School of Economics and Political Science. (Depository of the London County Council.)
INDIA: National Library, Calcutta.
  Central Secretariat Library, New Delhi.
  Parliament Library, New Delhi.
INDONESIA: Ministry for Foreign Affairs, Djakarta.
IRELAND: National Library of Ireland, Dublin.
ISRAEL: State Archives and Library, Hakirya, Jerusalem.
ITALY: Ministero della Pubblica Istruzione, Rome.
JAPAN: National Diet Library, Tokyo.[2]
MEXICO: Secretaría de Relaciones Exteriores, Departamento de Información para el Extranjero, México, D.F.
NETHERLANDS: Royal Library, The Hague.
NEW ZEALAND: General Assembly Library, Wellington.
NORWAY: University Library, Oslo.[1]
PERU: Sección de Propaganda y Publicaciones, Ministerio de Relaciones Exteriores, Lima.
PHILIPPINES: Bureau of Public Libraries, Department of Education, Manila.
PORTUGAL: Biblioteca Nacional, Lisbon.
SPAIN: Biblioteca Nacional, Madrid.
SWEDEN: Kungliga Biblioteket, Stockholm.
SWITZERLAND: Bibliothèque Centrale Fédérale, Berne.
TURKEY: National Library, Ankara.

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[1] Change in name.
[2] Receives two sets.

Union of South Africa: State Library, Pretoria, Transvaal.
Union of Soviet Socialist Republics: All-Union Lenin Library, Moscow.
United Nations: Library of the United Nations, Geneva, Switzerland.
Uruguay: Oficina de Canje Internacional de Publicaciones, Montevideo.
Venezuela: Biblioteca Nacional, Caracas.
Yugoslavia: Bibliografski Institut FNRJ, Belgrade.[2]

RECIPIENTS OF THE PARTIAL SETS

Afghanistan: Library of the Afghan Academy, Kabul.
Belgium: Bibliothèque Royale, Bruxelles.
Bolivia: Biblioteca del Ministerio de Relaciones Exteriores y Culto, La Paz.
Brazil: Minas Gerais: Departmento Estadul de Estatística, Belo Horizonte.
British Guiana: Government Secretary's Office, Georgetown, Demerara.
Cambodia: Les Archives et Bibliotheque Nationale, Phnom-Penh.
Canada:
  Alberta: Provincial Library, Edmonton.
  British Columbia: Provincial Library, Victoria.
  New Brunswick: Legislative Library, Fredericton.
  Newfoundland: Department of Provincial Affairs, St. John's.
  Nova Scotia: Provincial Secretary of Nova Scotia, Halifax.
Dominican Republic: Biblioteca de la Universidad de Santo Domingo, Santo Domingo.
Ecuador: Biblioteca Nacional, Quito.
El Salvador:
  Biblioteca Nacional, San Salvador.
  Ministerio de Relaciones Exteriores, San Salvador.
Greece: National Library, Athens.
Guatemala: Biblioteca Nacional, Guatemala.
Haiti: Bibliothèque Nationale, Port-au-Prince.
Honduras:
  Biblioteca Nacional, Tegucigalpa.
  Ministerio de Relaciones Exteriores, Tegucigalpa.
Iceland: National Library, Reykajavik.
India:
  Bombay: Sachivalaya Central Library, Bombay.
  Bihar: Revenue Department, Patna.
  Kerala: Kerala Legislature Secretariat, Trivandrum.
  Uttar Pradesh:
    University of Allahabad, Allahabad.
    Secretariat Library, Lucknow.
  West Bengal: Library, West Bengal Legislative Secretariat, Assembly House, Calcutta.
Iran: Imperial Ministry of Education, Tehran.
Iraq: Public Library, Baghdad.
Jamaica:
  Colonial Secretary, Kingston.
  University College of the West Indies, St. Andrew.
Lebanon: American University of Beirut, Beirut.
Liberia: Department of State, Monrovia.
Malaya: Federal Secretariat, Federation of Malaya, Kuala Lumpur.
Malta: Minister for the Treasury, Valletta.

[2] Receives two sets.

NICARAGUA: Ministerio de Relaciones Exteriores, Managua.
PAKISTAN: Central Secretariat Library, Karachi.
PANAMA: Ministerio de Relaciones Exteriores, Panamá.
PARAGUAY: Ministerio de Relaciones Exteriores, Sección Biblioteca, Asunción.
PHILIPPINES: House of Representatives, Manila.
SCOTLAND: National Library of Scotland, Edinburgh.
SINGAPORE: Chief Secretary, Government Offices, Singapore.
SUDAN: Gordon Memorial College, Khartoum.
THAILAND: National Library, Bangkok.
VIET-NAM: Direction des Archives et Bibliothèques Nationales, Saigon.

INTERPARLIAMENTARY EXCHANGE OF THE OFFICIAL JOURNALS

There are being sent on exchange through the International Exchange Service 108 copies of the daily issues of the *Congressional Record* and 86 copies of the daily issues of the *Federal Register*. Listed below are the names and addresses of the recipients of the official journals.

RECIPIENTS OF THE CONGRESSIONAL RECORD AND FEDERAL REGISTER

ARGENTINA:
  Biblioteca del Poder Judicial, Mendoza.[3]
  Dirección General del Boletin Oficial e Imprentas, Buenos Aires.
  Cámara de Diputados Oficina de Información Parliamentaria, Buenos Aires.
AUSTRALIA:
  National Library of Australia, Canberra.
  NEW SOUTH WALES: Library of Parliament of New South Wales, Sydney.
  QUEENSLAND: Chief Secretary's Office, Brisbane.
  VICTORIA: State Library of Victoria, Melbourne.[3]
  WESTERN AUSTRALIA: Library of Parliament of Western Australia, Perth.
BELGIUM: Bibliothèque du Parlement, Palais de la Nation, Brussels.[4]
BRAZIL:
  Biblioteca da Câmara dos Deputados, Brasilia, D.F.[4]
  Secretaria da Presidencia, Rio de Janeiro.[4]
CAMBODIA: Ministry of Information, Phnom-Penh.
CAMEROON: Imprimerie Nationale, Yaoundé.[3]
CANADA:
  Clerk of the Senate, Houses of Parliament, Ottawa.
  Library of Parliament, Ottawa.
CEYLON: Ceylon Ministry of Defense and External Affairs, Colombo.[4]
CHILE: Biblioteca del Congreso Nacional, Santiago.[4]
CHINA:
  Legislative Yuan, Taipei, Taiwan.[4]
  Taiwan Provincial Assembly, Taiwan[1]
CUBA:
  Biblioteca del Capitolio, Habana.
  Biblioteca Pública Panamericana, Habana.[3]
CZECHOSLOVAKIA: Ceskoslovenska Akademie Ved, Prague.[4]

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[1] Change in name.
[3] *Federal Register* only.
[4] *Congressional Record* only.

EGYPT: Ministry of Foreign Affairs, Egyptian Government, Cairo.[4]
FINLAND: Library of the Parliament, Helsinki.[4]
FRANCE:
  Bibliothèque Assemblée Nationale, Paris.
  Bibliothèque Conseil de la République, Paris.
  Library, Organization for European Economic Cooperation, Paris.[4]
  Bibliothèque du Conseil de l'Europe, Strasbourg.[1,4]
  Service de la Documentation Étrangère Assemblée Nationale, Paris.[4]
GABON: Secretary General, Assemblée Nationale, Libreville.[4]
GERMANY:
  Amerika Institut der Universität München, München.[4]
  Archiv, Deutscher Bundestag, Bonn.
  Bibliothek des Instituts für Weltwirtschaft an der Universität Kiel, Kiel-Wik.
  Bibliothek Hessischer Landtag, Wiesbaden.[4]
  Deutsches Institut für Rechtswissenschaft, Potsdam-Babelsberg II.[3]
  Deutscher Bundesrat, Bonn.[4]
  Deutscher Bundestag, Bonn.[4]
  Hamburgisches Welt-Wirtschafts-Archiv, Hamburg.
  Westdeutsche Bibliothek, Marburg, Hessen.[4,5]
GHANA: Chief Secretary's Office, Accra.[4]
GREAT BRITAIN:
  Department of Printed Books, British Museum, London.
  House of Commons Library, London.[4]
  N.P.P. Warehouse, H.M. Stationery Office, London.[3,6]
  Printed Library of the Foreign Office, London.[4]
  Royal Institute of International Affairs, London.[4]
GREECE: Bibliothèque Chambre des Députés, Hellênique, Athens.
GUATEMALA: Biblioteca de la Asamblea Legislativa, Guatemala.
HAITI: Bibliothèque Nationale, Port-au-Prince.
HONDURAS: Biblioteca del Congreso Nacional, Tegucigalpa.
HUNGARY: Országos Széchenyi Konyvtár, Budapest.
INDIA:
  Civil Secretariat Library, Lucknow, United Provinces.[3]
  Jammu and Kashmir Constituent Assembly, Srinagar.[4]
  Legislative Assembly, Government of Assam, Shillong.[4]
  Legislative Assembly Library, Lucknow, United Provinces.
  Kerala Legislature Secretariat, Trivandrum.[4]
  Madras State Legislature, Madras.[4]
  Parliament Library, New Delhi.
  Gokhale Institute of Politics and Economics, Poona.[4]
IRELAND: Dail Eireann, Dublin.[4]
ISRAEL: Library of the Knesset, Jerusalem.
ITALY:
  Biblioteca Camera dei Deputati, Rome.
  Biblioteca del Senato della Republica, Rome.
  International Institute for the Unification of Private Law, Rome.[3]
  Periodicals Unit, Food and Agriculture Organization of the United Nations, Rome.[3]

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[1] Change in name.
[3] *Federal Register* only.
[4] *Congressional Record* only.
[5] Three copies.
[6] Two copies.

IVORY COAST: Chef des Services Legislatifs, Assemblee Nationale, Abidjan.[4 7]

JAPAN:

Library of the National Diet, Tokyo.

Ministry of Finance, Tokyo.

JORDAN: Parliament of the Hashemite Kingdom of Jordan, Amman.[4]

KOREA: Library, National Assembly, Seoul.

LUXEMBOURG: Assemblée Commune de la C.E.C.A., Luxembourg.

MEXICO:

Dirección General de Información, Secretaría de Governación, Mêxico, D.F.

Biblioteca Benjamin Franklin, México, D.F.

AGUASCALIENTES: Gobernador del Estado de Aguascalientes, Aguascalientes.

BAJA CALIFORNIA: Gobierno del Estado de Baja California, Mexicali.[1]

CAMPECHE: Gobernador del Estado de Campeche.

CHIAPAS: Gobernador del Estado de Chiapas, Tuxtla Gutiérrez.

CHIHUAHUA: Gobernador del Estado de Chihuahua, Chihuahua.

COAHUILA: Periódico Oficial del Estado de Coahuila, Palacio de Gobierno, Saltillo.

COLIMA: Gobernador del Estado de Colima, Colima.

GUANAJUATO: Secretaría General de Gobierno del Estado, Guanajuato.[3]

JALISCO: Biblioteca del Estado, Guadalajara.

MÉXICO: Gaceta del Gobierno, Toluca.

MICHOACÁN: Secretaría General de Gobierno del Estado de Michoacán, Morelia.

MORELOS: Palacio de Gobierno, Cuernavaca.

NAYARIT: Gobernador de Nayarit, Tepic.

NUEVO LEÓN: Biblioteca del Estado, Monterrey.

OAXACA: Periódico Oficial, Palacio de Gobierno, Oaxaca.[3]

PUEBLA: Secretaría General de Gobierno, Puebla.

QUERÉTARO: Secretaría General de Gobierno, Sección de Archivo, Querétaro.

SINALOA: Dirección del Periódico Oficial 'El Estado de Sinaloa, Culiacan.[1]

SONORA: Gobernador del Estado de Sonora, Hermosillo.

TAMAULIPAS: Secretaría General de Gobierno, Victoria.

VERACRUZ: Gobernador del Estado de Veracruz, Departamento de Gobernación y Justicia, Jalapa.

YUCATÁN: Gobernador del Estado de Yucatán, Mérida.

NETHERLANDS: Koninklijke Bibliotheek, The Hague.[3]

NEW ZEALAND: General Assembly Library, Wellington.

NIGERIA:

Office of the Clerk of the Legislature, Enugu.[4]

Office of the Western Nigeria Legislature, Ibadan.[4 7]

NORWAY: Library of the Norwegian Parliament, Oslo.

PAKISTAN: Secretary, Provincial Assembly West Pakistan, Lahore.[4]

PANAMA: Biblioteca Nacional, Panama City.[4]

PHILIPPINES: House of Representatives, Manila.

POLAND: Kancelaria Rady Panstwa, Biblioteka Sejmowa, Warsaw.

RHODESIA AND NYASALAND: Federal Assembly, Salisbury.[3]

RUMANIA: Biblioteca Centrala de Stat RPR, Bucharest.

RWANDA: Service de la Législation, Cabinet du Président, Kigali.[3 7]

SENEGAL: Secrétaire-Général, Assemblée Nationale, Dakar.[4 7]

SIERRA LEONE: Office of the Clerk, House of Representatives, Freetown.[4 7]

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[1] Change in name.

[3] *Federal Register* only.

[4] *Congressional Record* only.

[7] Added during the year.

SPAIN: Boletin Oficial del Estado, Presidencia del Gobierno, Madrid.[3]
SWEDEN: Universitetsbiblioteket, Uppsala.
SWITZERLAND:
International Labour Office, Geneva.[3 6]
Library, United Nations, Geneva.
TANGANYIKA: Library, University College, Dar es Salaam.[4]
TOGO: Ministère d'État, de l'Interieur, de l'Information et de la Presse, Lome.
UGANDA: National Assembly of Uganda, Parliament House, Kampala.[4 7]
UNION OF SOUTH AFRICA:
CAPE OF GOOD HOPE: Library of Parliament, Cape Town.
TRANSVAAL: State Library, Pretoria.
UNION OF SOVIET SOCIALIST REPUBLICS: Fundamental'niia Biblioteka Obshchestvennykh Nauk, Moscow.
UPPER VOLTA:
Président de la Commission des Affaires Sociales et Culturelles, Assemblée Nationale, Ouagadougou.[4 7]
Chef de Cabinet, Présidence, Ouagadougou.[3 7]
URUGUAY: Diario Oficial, Calle Florida 1178, Montevideo.
YUGOSLAVIA: Bibliografski Institut FNRJ, Belgrade.[6]

During the fiscal year 1964, the International Exchange Service received for transmission publications weighing over 1 million pounds from foreign and domestic sources—the largest amount of publications received for transmission during any one year by the Service. The number and weight of the packages of publications received from sources in the United States for transmission abroad, and the number and weight of packages received from foreign sources intended for domestic addresses, are classified for fiscal 1964 in table 1.

Publications weighing 118,091 pounds were received during the year from foreign sources for distribution to addresses in the United States.

Publications weighing 621,353 pounds, 69.7 percent of the total received for transmission abroad, were forwarded by ocean freight at a cost to the Smithsonian Institution of $36,187 or approximately 5.8 cents per pound.

Packages of publications are mailed directly to the addresses in the countries that do not have exchange bureaus. During the past fiscal year publications weighing 269,773 pounds, 30.3 percent of the total received for transmission abroad, were mailed to the intended addresses, at a cost of $63,073 or approximately 23.4 cents per pound.

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[3] *Federal Register* only.
[4] *Congressional Record* only.
[6] Two copies.
[7] Added during the year.

Table 1.—*The number and weight of outgoing and incoming packages handled by the International Exchange Service, fiscal year 1964*

Classification	Received by the Smithsonian Institution for transmission			
	For transmission abroad		For distribution in the United States	
	Number of packages	Weight in pounds	Number of packages	Weight in pounds
U.S. parliamentary documents received for transmission abroad	744, 398	339, 842		
Publications received from foreign sources for U.S. parliamentary addressees			8, 297	11, 038
U.S. departmental documents received for transmission abroad	285, 071	289, 263		
Publications received from foreign sources for U.S. departmental addressees			5, 937	13, 749
Miscellaneous scientific and literary publications received for transmission abroad	205, 890	262, 043		
Miscellaneous scientific and literary publications received from abroad for distribution in the United States			54, 016	93, 304
Total	1, 235, 359	891, 148	68, 250	118, 091
Total packages received	1, 303, 609			
Total pounds received				1,009,239

The chart on the opposite page gives the comparative weight of the packages of publications received for transmission through the Service between the years 1850 and 1964, by 5-year periods.

Respectfully submitted.

J. A. Collins, *Chief.*

S. Dillon Ripley,
Secretary, Smithsonian Institution.

Chart 1.—*Comparative Weight of Packages Received for Transmission Through the International Exchange Service Between 1850 and 1964, by 5-Year Periods*

FIVE YEAR PERIOD	EACH COLUMN EQUAL TO 200,000 POUNDS	WEIGHT IN POUNDS
1850 - 1854		46,696
1855 - 1859		95,154
1860 - 1864		96,609
1865 - 1869		113,750
1870 - 1874		159,409
1875 - 1879		364,495
1880 - 1884		613,888
1885 - 1889		763,257
1890 - 1894		1,102,742
1895 - 1899		1,452,435
1900 - 1904		2,261,814
1905 - 1909		2,327,420
1910 - 1914		2,775,158
1915 - 1919	A.	1,532,483
1920 - 1924		2,754,213
1925 - 1929		2,833,276
1930 - 1934		3,270,382
1935 - 1939		3,206,444
1940 - 1944	B.	1,734,428
1945 - 1949		3,066,323
1950 - 1954		4,098,909
1955 - 1959		3,954,631
1960 - 1964		4,676,346

A. INTERRUPTION TO THE SERVICE DUE TO WORLD WAR I.
B. INTERRUPTION TO THE SERVICE DUE TO WORLD WAR II.

Report on the Bureau of American Ethnology

Sir: I have the honor to submit the following report on the field researches, office work, and other operations of the Bureau of American Ethnology during the fiscal year ended June 30, 1964, conducted in accordance with the act of Congress of April 10, 1928, as amended August 22, 1949, which directs the Bureau "to continue independently or in cooperation anthropological researches among the American Indians and the natives of lands under the jurisdiction or protection of the United States and the excavation and preservation of archeologic remains."

SYSTEMATIC RESEARCHES

Dr. Frank H. H. Roberts, Jr., devoted most of the first quarter of the fiscal year to office duties and to general supervision of the activities of the Bureau and the River Basin Surveys. In mid-October he went on extended sick leave and retired on June 5, 1964, after 37 years 10 months of service. During his absence from the office and the period from his retirement to the end of the fiscal year, Dr. Henry B. Collins assumed administrative responsibility for the Bureau as acting director, and Dr. Robert L. Stephenson functioned in a similar capacity for the River Basin Surveys.

In August, Dr. Henry B. Collins, anthropologist, made a trip to L'Anse aux Meadows, northern Newfoundland, on behalf of the National Geographic Society, to check the authenticity of an archeological site which its discoverer, Helge Ingstad, of Oslo, Norway, believed to be of Norse origin. As a result of his examination of the site, Dr. Collins was able to verify this conclusion. The ruins of sod-walled houses excavated by Mr. Ingstad at L'Anse aux Meadows are definitely not Indian or Eskimo, and there is nothing to indicate that they were the work of later English, French, or Portuguese fishermen. On the other hand, the house ruins and associated features are closely similar to those found at Viking sites in Greenland and Iceland. Thirteen radiocarbon dates, based on charcoal from the house ruins, cluster around the year A.D. 1000. This is the period of the Vinland voyages, when, according to the sagas, Leif Ericson, Thorfinn Karlsefni, and other Norsemen sailed westward and discovered the American mainland.

Dr. Collins continued to serve as a member of the board of governors of the Arctic Institute of North America, as a member of its publications committee and as chairman of the committees directing two of the Arctic Institute's projects—a Russian translation program and the *Arctic Bibliography.* The latter is a comprehensive reference work which abstracts and indexes in English the contents of publications in all languages and in all fields of science pertaining to the Arctic and subarctic regions of the world. This work, which is supported by a number of military and civilian agencies of the United States and Canada, began operating in 1947, and to date has published 11 large volumes containing abstracts of 69,455 scientific publications on the Arctic. The other Arctic Institute project being carried out under Dr. Collins' direction, *Anthropology of the North: Translations from Russian Sources*, continued its operations under a renewed grant from the National Science Foundation. The latest volume in the translation series, *Studies in Siberian Shamanism*, edited by Dr. Henry N. Michael, was published by the University of Toronto Press in December 1963.

Dr. Robert L. Stephenson was transferred on September 29, 1963, from chief of the Missouri Basin Project, River Basin Surveys, Lincoln, Nebr., to the regular staff of the Bureau of American Ethnology as assistant director of the River Basin Surveys. He has devoted his time to familiarizing himself with the activities of the Washington headquarters of the River Basin Surveys, to the general supervision of that unit, and to sorting materials and writing his reports on past field researches. In November he attended the Southeastern Archeological Conference in Macon, Ga. He spent the period November 29 to December 5 in Lincoln, Nebr., consulting with representatives of the National Park Service and State cooperative agencies on research plans for the River Basin Surveys for the coming year. On February 12–13 he participated in the annual meeting of the Committee for the Recovery of Archeological Remains, in Washington, D.C., and detailed the program of systematic researches of the River Basin Surveys. During May 7–9 he attended the annual meeting of the Society for American Archeology at Chapel Hill, N.C. On May 10 he was the featured speaker at the semiannual meeting of the Maryland Archeological Society in Washington, D.C., and presented an illustrated lecture on the "Archeology of the Middle Atlantic Seaboard Area."

During the early part of the fiscal year, Dr. William C. Sturtevant, ethnologist, was engaged in completing his paper on "Studies in Ethnoscience" (still in press at the end of the year) and in preparing for a year's field work in Burma. In July he flew to Gainesville, Fla., to work with Dr. Irving Rouse, of Yale University, and Dr. Charles

H. Fairbanks, of the University of Florida, on projects concerning the editing of the obituary and collected writings of the late Dr. John W. Goggin. He also advised the University's Department of Anthropology on the disposition of the Goggin manuscripts, notes, papers, etc., and outlined plans for the publication of nearly completed manuscripts.

Publications issued by Dr. Sturtevant during the fiscal year 1964 included the translation and annotation of "A Jesuit Missionary in South Carolina, 1569–70," by Father Juan Rogel, pp. 167–175 in *The Indian and the White Man* (edited by Wilcomb E. Washburn); (with John M. Goggin) "The Calusa, a Stratified, Non-Agricultural Society (with notes on sibling marriage)," pp. 179–219 in *Explorations in Cultural Anthropology: Essays Presented to George Peter Murdock* (edited by W. H. Goodenough); "Five Civilized Tribes," *Encyclopedia Britannica*, vol. 9, pp. 396–397; "Seminole," *Encyclopedia Britannica*, vol. 20, p. 313H; "John White's Contributions to Ethnology," pp. 37–43 in vol. 1 of *The American Drawings of John White*, 1577–1590 (edited by Paul H. Hulton and David B. Quinn); and obituary of John M. Goggin, 1916–1963, *American Anthropologist*, vol. 66, No. 2, pp. 385–394.

Dr. Sturtevant [1] left the country on October 4 for Burma, to undertake field work supported by a grant from the National Science Foundation.

From July to October Dr. Robert M. Laughlin, ethnologist, continued field work in Chiapas, Mexico, where he recorded and translated a series of 251 dreams of the Tzotzil Indians of Zinacantán, Chiapas. He discovered that dreams are recognized by the natives to be a form of mental telepathy, a two-way communications system, whereby the dreamer's soul is in contact with the divine and with the souls of fellow (usually hostile) mortals. Dreams are held to be an indication of an individual's success in withstanding enemy attack.

Dr. Laughlin spent November and December in Santa Fe, N. Mex., accompanied by two Zinacantec informants who provided additional material for the compilation of a Tzotzil dictionary. His time in Washington was devoted to continuing research on his dictionary which involved the study of 17th- and 18th-century Tzotzil-Spanish manuscripts. He selected much of his own textual materials for use by the Coordinated Study of Tzeltal-Tzotzil Drinking of the University of Rochester. Selections of music from Zinacantán and Martinique were contributed to the Cantometrics Research Project of Columbia University for cross-cultural analysis.

In collaboration with Dr. B. N. Colby, of the Laboratory of Anthropology, Museum of New Mexico, Dr. Laughlin initiated a computer

[1] Temporarily transferred to Smithsonian private roll.

analysis of the values expressed in Tzotzil myths and dreams. It is hoped that the results will demonstrate in specific terms the close relationship between mythic and oneiric expression.

A chapter on Zinacantec dream interpretation written by Dr. Laughlin was accepted for publication in *Ensayos Sobre Zinacantán* (E. Z. Vogt, ed.). His chapter, entitled "Tzotzil," for the *Handbook of Middle American Indians*, is in preparation.

In addition, Dr. Laughlin attended the 62d annual meeting of the American Anthropological Association (San Francisco, November 21–24) in company with his Zinacantec informants. A journal of their travels in Mexico and the United States was written by the informants in their native language. Dr. Laughlin conducted library research at Harvard University (May 27–29) and participated in an informal conference at Palo Alto (June 4–6) as a consultant for the Chicago-Harvard-Stanford Chiapas Aerial Survey Project.

RIVER BASIN SURVEYS

(*Prepared by Robert L. Stephenson, acting director, from data submitted by staff members*)

The River Basin Surveys, a unit of the Bureau of American Ethnology, continued its activities throughout the year. This unit was organized in 1945 to cooperate with the National Park Service and the Bureau of Reclamation of the Department of the Interior, the Corps of Engineers of the Department of the Army, and State and local institutions in the program for salvage archeology in areas to be flooded or otherwise destroyed by the construction of large dams. Its purpose has remained the same over the years and its activities during the current year were directed toward the same objectives. The research investigations during 1963–64 were supported by a transfer of $254,500 from the National Park Service and a carryover of $95,768 of Missouri Basin money to support investigations within the Missouri River Basin. Additional funds were available from two other sources. A previous grant from the Appalachian Power Co. had a carryover of $5,038 to support the research along the Roanoke River in southern Virginia at the Smith Mountain Project. Another earlier contribution by the Idaho Power Co. to support the researches in the Hells Canyon Reservoir area on the Snake River in Oregon and Idaho had a carryover of $4,080. The latter investigation was carried on as a cooperative project between the River Basin Surveys and the Museum of Idaho State University at Pocatello. The grand total of funds available for the River Basin Surveys in 1963–64 was $359,386.

Field researches consisted largely of surveys and excavations. Most

of the work was concentrated in the digging or testing of sites, but surveys were made in four new reservoir areas in North Dakota and one new reservoir area in South Dakota. At the beginning of the fiscal year there were 12 crews at work. One field crew was operating in the Smith Mountain Reservoir area in southern Virginia, seven parties were at work in the Oahe and Big Bend Reservoir areas of South Dakota, one party was excavating in the Yellowtail Reservoir area in Montana and Wyoming, and another was working in the Pony Creek drainage area in Iowa. A special crew was in Lawrence, Kans., studying human skeletal remains from the Oahe Reservoir, and one survey team was at work in North and South Dakota. During the second quarter of the year, parties worked briefly in Alabama, Nebraska, and Wyoming. In May two brief surveys were made in South Dakota, and in June nine parties began major operations in the Missouri Basin, where they were at work at the end of the fiscal year.

As of June 30, 1964, archeological surveys and excavations had been made, since the start of the salvage program, in a total of 269 reservoir areas, located in 29 States, as well as in 2 lock projects, 4 canal areas, and 2 watershed areas. Since 1946, when the field work of the program got underway, 5,040 sites have been located and recorded; of that number 1,186 were recommended for excavation or limited testing. Because of the emergency conditions under which the salvage program must operate, it is rarely possible to fully excavate a site. "Excavation," as used here, usually means that about 10 percent of the site was dug. By the end of the fiscal year, 526 sites in 55 reservoir basins and 2 watershed areas had been tested or excavated to a degree where good information about them had been obtained. These sites range in nature from simple camping areas, once occupied by early hunting and gathering Indians of some 10,000 years ago, to village remains left by the historic Indians of the mid-19th century and the remains of frontier trading posts and military installations of European origin.

The results of these extensive investigations have been incorporated in technical reports that have been published in various scientific journals, in Bureau of American Ethnology Bulletins, and in the Smithsonian Miscellaneous Collections. *River Basin Surveys Papers Nos. 33–38*, constituting *Bureau of American Ethnology Bulletin 189*, were released in June. These papers pertain to excavations carried out in North Dakota, South Dakota, and Kansas. Reports of other excavations in the Dakotas and in Oregon and Idaho are now being assembled for another Bulletin. Staff members cooperated throughout the year with representatives of other Federal agencies in the preparation of short popular pamphlets about some of the major reservoir projects.

As in previous years, the River Basin Surveys received helpful cooperation from the National Park Service, the Bureau of Reclamation, the Corps of Engineers, the Geological Survey, and numerous State and local institutions. The National Park Service continued to serve as liaison, among the various agencies, both in Washington and in the field, and prepared budget estimates and justifications for the funds needed to support the salvage program. Party leaders were assisted in many ways by personnel of all the cooperating agencies, and the relationship was outstanding in all areas.

General direction and supervision of the program were continued from the main office in Washington. Work in the Missouri Basin was directed by the field headquarters and laboratory in Lincoln, Nebr. The project in Virginia was supervised by the Washington office.

Washington office.—Dr. Frank H. H. Roberts, Jr., continued the direction of the entire River Basin Surveys from the main headquarters in the Bureau of American Ethnology until October 15 when he went on sick leave. At that time, Dr. Robert L. Stephenson, who had been transferred from the field headquarters in Lincoln, Nebr., on September 30, to be assistant director, was designated acting director and served in that capacity during the remainder of the year. Carl F. Miller and Harold A. Huscher, archeologists, were based at the headquarters office throughout the year.

At the beginning of the year Mr. Huscher was in the Washington office working on his materials from the Walter F. George Reservior area and other areas along the Chattachoochee River. At the end of October he visited the recently flooded Walter F. George Reservior area to recheck some of the sites along the shore that were beginning to erode, and to examine sites in the vicinity of Columbus, Ga., and Montgomery, Ala., that are threatened with destruction from industrial development. During the period December 12–25, he returned to Montgomery, Ala., to assist the Montgomery Museum of Fine Arts in the emergency salvage of parts of the Shine Mound site, which was threatened with destruction by a municipal waterplant. This work was done in cooperation with David W. Chase, curator of the Montgomery Museum of Fine Arts.

On September 6–8, Mr. Huscher attended the joint Plains-Pecos Conference at Fort Burgwin, Taos, N. Mex., where he presented a paper on "Plains Influences Directly Recorded in Navajo and Western Apache Culture." In November he attended the Southeastern Archeological Conference in Macon, Ga., and presented a paper entitled "A Summary of the Walter F. George River Basin Surveys Salvage Program." His paper read at the preceding conference was published under the title "The Archaic of the Walter F. George Reservior Area" in *Proceedings of the 19th Southeastern Archeological Conference*,

Bulletin 1, March 1964. He attended the Eastern States Archeological Conference during November 9–10 and there presented a report on "The Cool Branch Site (9QU5), Quitman County, Georgia, a Fortified Mississippian Town with Tower Bastions." He participated in a roundtable discussion of current Early Man problems at the annual meeting of Section H of the American Association for the Advancement of Science, in Cleveland, Ohio, December 26–30. Early in May he attended the annual meeting of the Society for American Archeology in Chapel Hill, N. C., and read a paper, "The Standing Boy Flint Industry, an Early Archaic Manifestation on the Chattahoochee River in Alabama and Georgia," which consisted of an interim report on three archeological sites near Columbia, Ala. The latter paper and an ethnographic background paper on aboriginal salt trade, "Salt Traders of Cibola," have been accepted for publication in professional journals.

At the beginning of the year Mr. Miller was in charge of a field party in southern Virginia. On July 28 this project was brought to a close and he returned to the office in Washington. During the remainder of the year he devoted his time to research on some of his past fieldwork. He completely revised and enlarged his preliminary manuscript on "Prehistoric Occupations of the Ft. Lookout Site (39-LM57), Ft. Randall Reservior, South Dakota." He had two papers accepted for publication in *Southern Indian Studies:* "A Napier-like Pottery Vessel from Russell Cave" and "Human-headed Adornos from Western Georgia." He had one paper accepted for publication in *The Masterkey:* "Bone Flutes from Southern Virginia." He attended the annual meetings of the Southeastern Archeological Conference in Macon, Ga., early in November and presented a paper on "The Appearance of Certain Projectile Points through Time at Russell Cave, Alabama." On December 30 he presented a paper at the annual meeting of the American Association for the Advancement of Science, in Cleveland, Ohio, entitled "Paleo-Indian and Early Archaic Projectile Point Forms from Russell Cave, Northern Alabama." In February he served as judge at two science fairs in Alexandria, Va., where he evaluated 195 public-school science exhibits. He prepared a bibliography on "Hopewell Culture" and one on "The Red Paint People" to answer inquiries from college students.

On March 21 Mr. Miller presented a paper, "The Archeology of Southern Virginia," at the meeting of the Shenandoah chapter of the Archeological Society of Virginia, in Strasburg, and while there examined several local collections of Indian materials and advised the chapter on their plans for a spring excavation program. During May 7–9 he participated in the annual meeting of the Society for American Archeology at Chapel Hill, N.C., and presented a paper on "The

Archeological Horizons within Russell Cave, Alabama." His article "Polyhedral Cores from Northeastern Kansas," published in the *Plains Anthropologist*, was reprinted in *The Chesopican*, a journal of Atlantic coast archeology. His monograph "The Archeological Investigations at the Hosterman Site (39PO7), Oahe Reservior Area, Potter County, South Dakota" was published as *River Basin Surveys Paper No. 35* in *Bureau of American Ethnology Bulletin 189*.

Missouri Basin.—At the end of its 18th year of operation, the Missouri Basin Project was well established in new quarters at 1835 P Street, Lincoln, Nebr. Although the move to the new location was made during fiscal year 1963, much of the new physical plant was not completed until well into the first quarter of 1964. For the first time in many years the Project has had enough space to meet with its current and immediately foreseeable needs. Office accommodations are now adequate, storage problems have been eased, and processing facilities are vastly improved.

Activities during fiscal year 1964 included large-scale excavations, surveys, processing and analysis of materials, preparation of manuscripts, and the reporting of archeological results. During the summer months, major efforts were devoted to excavations; the remainder of the year was devoted largely to analyses and the preparation of reports. The special chronology program begun in January 1958 was continued throughout the year. Dr. Robert L. Stephenson served as chief of the Project through the first quarter of the fiscal year. At the beginning of the second quarter he was succeeded by Dr. Warren W. Caldwell, who continued in the position through the remainder of the year.

At the beginning of the year the permanent staff, in addition to the chief, consisted of 9 archeologists, 1 administrative assistant, 1 secretary, 1 administrative clerk, 2 clerk-typists, 1 scientific illustrator, 1 photographer, and 4 museum aides. The temporary staff consisted of 73 persons. There were 3 archeologists, 2 physical anthropologists, 4 cooks, and 64 field crewmen.

During July and August, 12 field crewmen were added to the temporary staff. By the end of the last week in September the employment of all the field crewmen and cooks had been terminated, with the exception of one crewman who was later transferred to the permanent staff as museum aide. The services of all the other temporary employees were terminated by early October. Other changes in the permanent staff were: termination of positions of one museum aide, one archeologist, and the administrative clerk; the death of one museum aide, and the appointment of one museum aide and one laborer. The chief was transferred to the Bureau of American Ethnology on September 30. Additions to the temporary staff during June were 2 archeologists, 5 cooks, and 66 field crewmen.

At the end of the fiscal year the permanent staff consisted of 19 persons; these were, in addition to the chief, 7 archeologists, 1 administrative officer, 1 secretary, 1 administrative clerk (typist), 1 clerk-typist, 1 scientific illustrator, 1 photographer, 4 museum aides, and 1 laborer. The temporary staff consisted of 73 persons. There were 2 archeologists, 5 cooks, and 66 field crewmen.

During the year there were 24 Smithsonian Institution, River Basin Surveys, field parties at work in the Missouri Basin. Eleven of these were in operation during July and August, 2 during October and November, and 11 during June.

At the beginning of the year John J. Hoffman and a crew of 10 men were excavating at the La Roche sites (39ST9, 39ST232)[2] in the Big Bend Reservoir of central South Dakota. Site 39ST9, on the right bank of the Missouri near the mouth of P L creek, consists of about 90 house depressions scattered over an area of about 80 acres. Seven circular houses were excavated, all of which were essentially similar and which appear to be representative of the Chouteau Aspect.

The site also produced evidence of the Grand Detour Phase, an early development within the prehistoric Middle Missouri Tradition, as well as a small oval structure assignable, on the basis of the ceramics, to the Plains Woodland Phase. Fortunately, the stratigraphic evidence is clear. The Plains Woodland component precedes the Grand Detour component which in turn underlies the principal Chouteau occupation. While these temporal relationships have been recognized for some time, there have been few instances of such satisfactory superimposition.

Site 39ST232 occupies something less than 40 acres of level terrace 1½ miles north of 39ST9. Of the six or seven depressions visible, two were investigated. Both proved to contain circular houses of the Chouteau Aspect. However, one was distinctive in its large diameter (75 feet) and in the presence of six central support posts instead of the usual pattern of four. On the basis of artifacts and architectural evidence, the Chouteau components of 39ST232 and 39ST9 appear to be intimately related. The field party completed work on August 30, after 79 days in the field.

A second field party of nine men, directed by Richard E. Jensen, was at work in the cul-de-sac in the central part of the Big Bend Reservoir. This region, on the left bank of the Missouri, within the great bend that gives the reservoir its name, contains a large number

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[2] Site designations used by the River Basin Surveys are trinomial in character, consisting of symbols for State, county, and site. The State is indicated by the first number, according to the numerical position of the State name in an alphabetical list of the United States; thus, for example, 32 indicates North Dakota, 39 indicates South Dakota. Counties are designated by a two-letter abbreviation; for example, ME for Mercer County, MN for Mountrail County, etc. The final number refers to the specific site within the indicated State and county.

of archeological sites. Although 10 of them were excavated or tested by the field group, results were not encouraging. Apparently the area was occupied quite extensively but cultural debris is scanty and the habitation sites thin.

At the Gregg site (39HY222), one of the largest in the pocket, portions of two earth lodges were excavated and five interhouse areas were tested. A single circular lodge and several tests were dug at the Fry site (39HU223), two lodges were exposed at site 39HU224 nearby, and a lodge and two large cache pits were cleared at the Hawk site (39HU238). Architectural features were not found at the remaining sites, but several clusters of exterior cache pits were cleared at the Saint John site (39HU213) and artifact collections were made at sites 39HU225, 39HU230, 39HU231, 39HU249, and 39HU250.

The earth-lodge structures excavated within the area of the cul-de-sac are all quite similar. Each was circular, with an irregular pattern of wall posts and four central supports. Entrance passages, where found, opened to the south or southwest. A small central hearth was characteristic and there were usually secondary firepits and one or more small basin-like or bell-shaped cache pits.

Ceramics were preponderantly simple-stamped, with Talking Crow and "Category B" rims most usual. Other artifacts were not distinctive, and except for several copper pendants and an iron blade hafted in a split bison rib from the Hawk site, there was no evidence of European contact.

On August 12 Jensen transferred his field party to the right bank of the Missouri where he assisted Hoffman in the excavation of the La Roche sites. The party completed work on August 23, after 72 days in the field.

At the beginning of the year, a third party of nine men, directed by William J. Folan, was assisting John J. Hoffman in excavations at the La Roche sites. On July 16 the Folan party moved to the left bank of the Missouri to begin work at the Chapelle Creek or Grandle site (39HU60), a large, fortified, multicomponent village in the central Big Bend Reservoir. Extensive trenching, exposing sections of three houses, a section of the defensive ditch, and a number of other features, was completed. Evidence of the earliest occupation consists solely of artifacts that are invariably found in the prehistoric, rectangular house complexes of the Big Bend region. The second component consists of the fortified settlement proper, which seems to be attributable to the historic Stanley-Le Beau complexes usually regarded as Arikara. The uppermost deposits contain additional European materials that are suspected to be the remains of a small (and poorly documented) trading post. In view of our present knowledge of the early history of the Big Bend region, it may be difficult, if not impos-

sible, to distinguish the traders' remains from those of the 18th-century Arikara.

During the first half of the field season the Folan group shared camp facilities with the Hoffman crew. The party completed work in August 30, after 79 days in the field.

At the beginning of the year a fourth party of five men, directed by G. Hubert Smith, was investigating historic sites within the Big Bend Reservoir. Excavations were made at the Red Cloud Agency (39LM247), on the right bank of the Missouri near Medicine Creek. The Agency, established for the Oglala Sioux, under Red Cloud, was used only briefly (1877–78) before the group was settled permanently on the Pine Ridge Reservation. Although little survived at the Red Cloud site (apparently the buildings had been systematically removed), some structural details were recovered together with a small group of representative specimens.

A thorough search was made of Dorion or Cedar Island, near the mouth of Cedar Creek, for the site of a trading post established in 1802 or 1803 by Regis Loisel. Despite excellent descriptions left by members of the Lewis and Clark Expedition, the post could not be located; however, another site (39HU301) found on the island was partially excavated. Cultural remains were not abundant but the appearance of the site and the presence of a number of machine-made objects suggest that the site was occupied during the 1860's by White "squatters" who supplied wood for steamboat fuel.

An intensive reconnaissance was made near the mouth of Medicine Creek, continuing a search begun some years ago for the Fort Defiance (or Bouis) trading post known to have been in existence in the 1840's. Although there were several hopeful leads, the search was fruitless. The Smith party shared camp facilities with Hoffman's crew. They returned to Lincoln on August 30 after 79 days in the field.

Three field parties were at work in the Oahe Reservoir at the beginning of the fiscal year. The first, a crew of 10 men, directed by Robert W. Neuman, was excavating at two prehistoric sities in Dewey County on the right bank of the Missouri near Mobridge, S. Dak. The Grover Hand Mounds (39DW240) include five tumuli, one of which was excavated by Neuman in 1963. Two additional examples were dug during the current year. The first was 90 feet in diameter and slightly more than 4 feet high. It covered a central subfloor burial pit containing about 23 secondary human burials of both sexes and various ages, some of which were sprinkled with hematite. The burials were in association with a number of implements and ornaments of bone and stone. Support logs overlay the burial pit, and above was another secondary burial partly covered by an inverted basket and associated with stone and shell artifacts. On the mound floor, adjacent to the

pit, were the partially articulated skeletons of at least six bison. The second mound was much the same as the first. However, the burial pit did not contain more than 12 individuals, and there were no human remains above.

Artifact materials from the two mounds included a few cord-paddled pottery cherds, rentalium, busycon and olivella ornaments, an antler pin, worked antler butts and tines, bone awls, beads, serrated fleshers, beaver incisors, stone projectile points, matting, pigments, and a considerable variety of other materials. On the basis of burial pattern and the artifacts excavated, the Grover Hand Mounds show a very close relationship to the neighboring Swift Bird Mounds (39DW233) and to the Boundary and Baldhill Mound sites in North Dakota.

At the end of July the Neuman party shifted to the Stelzer site (39DW242) to continue excavations begun during 1963. This site is a large camp area only a short distance from the Grover Hand Mounds. The occupation level, less than 1½ feet below the present surface, is characterized by scattered midden heaps, small firepits, and circular pits filled with detritus. There were also 17 randomly distributed bison long bones stuck vertically into the occupation surface. Artifacts from the Stelzer site, particularly projectile points and pottery, are closely comparable to those from the adjacent mound sites. There seems to be good evidence here for the first direct relationship between burial mounds and a habitation site in the northern Plains.

The party concluded work on August 23 after 74 days in the field. Subsequently, Neuman and a single crewman visited previously unreported mound sites along the Sheyenne River in Barnes County, N. Dak., and another above Wolfe Creek in the James River Valley, S. Dak.

A second party of seven men, under the leadership of Oscar L. Mallory, conducted test excavations at a large group of sites in Dewey County, along the right bank of the Missouri a short distance upstream from the mouth of the Moreau River. Site 39DW231, a small village on a terrace spur defended by two ditches, was tested extensively. A midden area, part of a circular house, and sections of the defensive system were exposed. Present evidence suggests that the principal occupation falls within the Chouteau Aspect and appears to be related to the Potts (39CD19) and No Heart (39AR1) villages of northern South Dakota.

A second fortified village, 39DW1, situated at the mouth of the Moreau River, was also tested. It differs from 39DW231 in that it lay on a higher terrace and was completely surrounded by a defensive ditch. The ceramic collections have much in common but apparently differences are such that they cannot be related on the focus level.

The remaining sites investigated, 39DW230, 39DW229, 39DW228, 39DW253, and 39DW254, were unfortified; pottery attributed to the La Roche horizon was usual. Portions of houses were excavated at 39DW228, 39DW229, and 39DW230. In each case the houses were circular with a central firepit and four central roof supports.

A number of additional sites were mapped or examined and a brief period was devoted to explorations at the Stelzer site. The latter is quite large, extending along the river for at least three-quarters of a mile. Mallory's tests were placed near the eastern end of the site. The pottery found here was identical to that found by Neuman's continuing excavations near the western edge. The Mallory party shared camp facilities with the Neuman crew, and returned to Lincoln on August 23 after 74 days in the field.

A third party of 12 men was directed by Dr. Alfred W. Bowers of the University of Idaho but temporarily attached to the Smithsonian Institution. The Bowers crew excavated at three small fortified village sites in the immediate vicinity of Mobridge, S. Dak. At the Red Horse Hawk site (39CO34), on the right bank of the Missouri, continuing work begun in the summer of fiscal year 1963, the excavation of 15 shallow circular houses was completed and the fortification ditch was tested in several places. This village, which is probably protohistoric, has produced a wealth of museum display specimens and is one of the two or three completely excavated sites within the Oahe Reservoir.

Work was also renewed at the Davis site (39CO14), a fortified village adjacent to the Red Horse Hawk site, continuing 1963 excavations. During the current season investigations were hampered by drought conditions which made the soil both intractable and "unreadable." With the use of a water wagon and power equipment, one lodge was completely excavated and the covering fill was removed from four others, but work could be carried no further.

The Davis site is an exceedingly important one because it appears to bridge the temporal gap between the rectangular and circular house complexes. The early component at the Davis site is distinctive in that lodges are placed within the bastions at the corners of the fortification, thus limiting the entrance passage to a narrow lane around the lodge.

Work was begun at the Larson site (39WW2), a small compact village on the left bank of the Missouri River south of Mobridge. The site consists of 29 circular depressions tightly clustered within an oval fortification ditch. Ten of the lodge depressions were trenched and two were completely excavated. The latter seem to have been rebuilt several times, but each new construction was smaller than the previous one. The most recent occupation seems to have been brought to an

end by the smallpox epidemic of A.D. 1780. There is no documentary evidence to this effect but human remains were strewn over the lodge floors. The skeletons of at least 30 individuals were exposed in one house, 8 in another, and there is evidence of additional skeletons in the remaining lodges. Since the deaths do not appear to have been due to violence, epidemic disease is inferred. In addition to the historic component or components at the Larson site, there are indications of an earlier Woodland occupation.

Bowers also conducted a limited survey along the now eroding banks of the Oahe Reservoir. A large collection of artifacts and bison bone was secured from the Rygh (39CA4) and Bamble (39CA6) villages where shoreline cutting has been extensive. Since the origin of these materials can be localized within the respective sites, they will be exceedingly useful for comparative studies. The party completed work on September 7 after 89 days in the field.

At the beginning of the fiscal year a field crew of five men, directed by Wilfred M. Husted, was excavating in the Yellowtail Reservoir along the Big Horn River of southern Montana and northern Wyoming. At the Mangus site (24CB221), a small rock shelter on the left bank of the river in Carbon County, Mont., three distinct occupation levels were found, the most recent of which was Late Prehistoric. A variety of artifacts was recovered here, including small triangular projectile points with and without side notches, stone knives, scrapers, fragments of sewn hide, cordage, and basketry. The middle zone carried obvious evidence of human use, but artifacts were too few to identify the nature of the occupation. The lowest level contained Agate Basin points, knives, scrapers and a mortar and pestle. Subsequently, a radiocarbon date of 1070 ± 70 B.P. (A.D. 880) was obtained from charcoal in a roasting pit found in the Late Prehistoric level, and two dates, 8690 ± 100 B.P. (6740 B.C.) and 8600 ± 100 B.P. (6650 B.C.) were secured from charcoal from the Agate Basin level.

Three other rock shelters in the vicinity, the Ledge site (24BH 252), the Greene site (24BH 253), and site 24BH255, all in Big Horn County, Mont., yielded artifacts of the Late Prehistoric Period. The Red Earth site (24BH251), another small shelter, contained a Late Prehistoric level, an unidentified occupation characterized by shallow, circular firepits, numerous small flakes, a mano and knife fragments.

Site 24BH 250, also in Big Horn County, Mont., was a small shelter with the entrance barricaded with rocks and juniper branches. A large fireplace outlined by rocks was intact on the surface, and below it was another containing burned stones and associated with a triangular projectile point.

A large, shallow, rock-filled firepit was excavated at site 24BH257, a small shelter formed by a large block fallen from the canyon wall.

Three corner-notched projectile points and several flakes were in association with the firepit. Until this site was excavated only simple triangular points or triangular points with side notches had been found with such firepits.

Three firepits, projectile points, scrapers, and a variety of worked flakes were found in tests at 24BH210, a large open site in Big Horn County. Two additional open sites, 24BH254 and 24BH259, were located in a badly eroded area, and tests showed that artifacts were restricted to the surface.

Site 24BH204 at the mouth of Porcupine Creek was tested but with negative results. Animal bone was abundant but it may have originated from gold camps that once operated at this location. Site 24BH214, about 1 mile above the mouth of Porcupine Creek, was only slightly more productive. Artifacts were limited to a corner-notched projectile point and a few scrapers.

Late in the season, the Husted party made exploratory tests at site 48BH217, in Big Horn County, Wyo., a short distance south of the Montana border. An Agate Basin point was found here in the course of land leveling for a cabin. Although tests were extensive, little of significance was recovered. The party completed its work on August 29 after 72 days in the field.

Another field party of nine men, under the direction of Lionel A. Brown, was working in the Pony Creek watershed in southwestern Iowa. A survey of the area added a number of new sites to the record, a number of tests were made, and five sites were excavated. Unfortunately, most of the endangered sites examined by the field party had been damaged in some degree by erosion or cultivation; nonetheless, architectural remains were found at four of them.

Two square houses were excavated at the Stonebrook Village (13ML219) and fragments of house floors were found at both the Downing (13ML218) and Steinheimer (13ML222) sites. The house structures ranged from 20 to 30 feet square, with deep vertical walls and entrances approaching 15 feet in length. The associated artifacts include ceramics of the Beckman and McVey series, clay effigies and pipestems, side-notched projectile points, ovoid to triangular knives, planoconvex end scrapers, pecked and chipped celts, but surprisingly very little worked bone.

The Thomas site (13ML204) contained a mixture of pottery primarily representative of the Woodland horizon and the Central Plains Tradition. The rimsherd collection includes examples of Sterns Creek, Beckman Ware, Swoboda Ware, and one example classified as Anderson Low Rim. The primary feature at the site was a pit, 20 feet square, similar to house pits reported for the Woodland of eastern Nebraska.

The Lungren site (13ML224) is an archaic camp first noted at a depth of 10 feet below the surface in a high cutbank. The cultural deposit proved to consist of a narrow (ca. 2 inches thick) zone of charcoal-stained soil mixed with large quantities of chipping debris and bone fragments. The only projectile point recovered is side-notched with basal grinding. It is similar to those from the Long Creek site in Saskatchewan, the Logan Creek and Spring Creek sites in Nebraska, and the Simonsen and Hill sites in Nebraska. Other artifacts include triangular to ovoid knives, small planoconvex end scrapers, hammerstones, chipped celts and choppers. Bone artifacts were absent. Several midden areas and a basin-shaped firepit constitute the only nonartifact features of the deposit. The party completed work on August 30 after 81 days in the field.

A special field party consisting of a varying number of students directed by Dr. William M. Bass III, assisted by Walter Birkby, was working in the laboratory at the University of Kansas, Lawrence, Kans., at the beginning of the fiscal year. Dr. Bass was continuing a study of the human skeletal remains and burial patterns from the Sully site (39SL4) begun in 1957.

A total of 557 burials was excavated from the cemeteries at the Sully Village. This is the largest single sample from a site in the Plains. It is not likely to be equaled in the immediate future. If the ethnic affiliation of the site is substantiated, the sample provides a baseline for the study of the early historic Arikara population.

In addition to observations and metric analyses, the group tabulated data on burial orientation, burial goods, and grave types. At the same time, three members of the University of South Dakota medical staff examined the physical material to record the incidence of nose, throat, and ear diseases occurring the population. Bass completed his study on August 2 after 63 days of work.

A field party, consisting of a crew of two men under the leadership of Dr. Elden Johnson, of the University of Minnesota, but temporarily attached to the Smithsonian Institution, began work on June 22 surveying several small reservoirs in North Dakota. A single, very thin, habitation site (39BE1), was found at the James River damsite in Beadle County, S. Dak. Although the area was trenched extensively, the results were minimal. No additional sites were found within the proposed reservoir, but a number of local collections that originated in adjacent areas were examined. Since the James River Dam is part of the much larger Oahe Diversion Project, these collections will become important for future research when the larger project is activated.

The Garrison Diversion Project proposes construction of four major reservoirs and an extensive system of feeder canals within eastern

North Dakota. Archeological work during the current year was concentrated within the reservoir areas since the canal routes are not yet established. The Taayer Reservoir east of Oakes, N. Dak., is presently an open water slough. No sites were found to be endangered but a probable bison kill site (32SA1) was reported here in the 1930's when the reservoir was dry. A "stone ring" site (32SA2) was recorded by the survey party but it lies in the uplands outside of the reservoir. Hamburg Reservoir on the upper James River produced no sites. New Home Reservoir, in McLean County, N. Dak., east and south of the Garrison Dam, is in a long glacial drainage trench. Only a single site, 32ML212, was found here. It consisted principally of bison bone eroding from a cutbank but a number of chalcedony flakes were found in association.

The Lone Tree Reservoir, which will include the headwaters of the Sheyenne River, held a number of sites and others were found in the immediate vicinity. Probably the most significant within the reservoir is 32SH2, a large complex of boulder burial mounds. At least 14 mounds are included, and associated habitation sites are possible. The party completed its survey on September 20. Because work was intermittent, the field season totaled only 49 days.

A postseason (October 21–November 4) field party of two men, directed by Wilfred M. Husted, excavated at Fort Laramie National Historic Site, testing in four localities that will be affected by future expansion of visitor facilities. The remains of what is probably the Ward anad Guerrier trading post were found, as well as evidences of an aboriginal occupation. The latter was far too scanty to even hazard an ethnic or archeological affiliation.

Late in September representatives of the Nebraska Game, Forestation and Parks Commission contacted the Missouri Basin Project concerning certain stone and pottery artifacts found during biological research in the Little Nemaha drainage of southeastern Nebraska. The artifacts examined by the Missouri Basin Project staff included materials suggesting the presence of Stearns Creek, Logan Creek, and Agate Basin complexes. On November 12, after the heavy summer vegetation was gone, Robert W. Neuman reexamined the area in company with Nebraska game biologists. Previous find spots were examined on Brownell Creek and Wolf Creek, but unfortunately the artifacts found to date have been secondary deposits and no true occupation sites were discovered.

Cooperating institutions working in the Missouri Basin at the beginning of the fiscal year included the University of Montana, the University of South Dakota, the University of Nebraska, the University of Missouri, and the Kansas State Historical Society.

Dr. Dee C. Taylor of the University of Montana continued the

shoreline survey of Fort Peck Reservoir of east-central Montana, locating archeological sites exposed by shoreline erosion. Robert Gant of the W. H. Over Museum, University of South Dakota, surveyed the shoreline of Lewis and Clark Lake (the former Gavins Point Reservoir). Dr. Preston Holder, assisted by James Marshall with a crew of students from the University of Nebraska, began salvage excavations in the Glen Elder Reservoir of northwestern Kansas. Several University of Missouri field parties, directed by Dr. Carl H. Chapman, excavated in the Kaysinger Bluff, Stockton, and Meramec Basin Reservoirs of Missouri. Each of these field parties operated under agreements with the National Park Service and the Smithsonian Institution in the Inter-Agency Salvage Program.

The 1964 field season began with two small survey teams examining sites in the upper Big Bend Reservoir. During the winter of 1964 the Missouri Basin Project staff had become aware that the waters behind the Big Bend Dam were rising faster than had been anticipated. Under the circumstances it was impossible to plan fieldwork for the approaching summer season without a close check on the changing conditions. On April 6 and 7, Richard E. Jensen and Oscar L. Mallory of the Project staff visited archeological sites along the left bank of the reservoir between Chapelle Creek and the city of Pierre. Severe weather conditions made it impossible to examine other areas, but as of that time water damage did not appear to be extensive. The reservoir level had reached a point just below many sites, and at least one, 39HU60 at Chapelle Creek, was then an island. Another reconnaissance was made by Jensen and Lionel A. Brown on May 7 and 8, but despite a slight interim rise of water level, the archeological situation had not changed significantly.

On June 9, a group of seven men directed by Wilfred M. Husted, began work in the Yellowtail Reservoir of Montana and Wyoming. This is the third and last season of excavation within the reservoir area. Previously, Smithsonian Institution field parties had concentrated in the lower and central parts of the reservoir. This year excavations are restricted to the upper Big Horn Canyon, thus completing the investigation of major sites within the reservoir. At the end of the fiscal year the crew was surveying within the upper reservoir.

On June 10 three additional field parties began work within the Big Bend Reservoir of central South Dakota. The first, a group of nine men directed by Richard E. Jensen, was carrying out large-scale testing at the Sommers site (39ST56) on the right bank of the Missouri adjacent to the La Roche sites. It is one of the most significant villages of the Middle Missouri Tradition surviving within the reservoir. The village contains at least 70 house depressions and has a particularly

thick mantle of debris. It is probable that two or more seasons of work will be required to secure an adequate sample from the site. As a consequence, the current excavations are exploratory, designed to provide an outline for further work. As of the end of the fiscal year, tests were underway in two long-rectangular houses in preparation for the use of power equipment to remove the heavy layer of overburden.

A second field party of 11 men, under the leadership of John J. Hoffman, was excavating at site 39ST17, a compact fortified village on the right bank of the Missouri near the mouth of Fort George Creek. The site is a relatively late one and probably can be attributed to the Arikara of the 18th century. Since the village is small, it is planned to excavate the entire occupied area. By the end of the fiscal year several tests were completed and a small circular house was exposed. Artifacts were few but indicate an affiliation with the Phillip Ranch site. The Hoffman and Jensen parties shared a camp near Fort George Creek, only a short distance from 39ST17.

A third party, consisting of eight men, directed by Lionel A. Brown, was working at the Chapelle Creek site, 39HU60, continuing excavations begun during the summer of 1963. A considerable amount of material has already been excavated from the site, but much of it is inconclusive. The purpose of the Brown party is to find the necessary relationships essential to bring the previous work into focus. At the end of the fiscal year the ravages of the past winter had been repaired and excavation of a shallow earth lodge of the historic period was well underway.

On June 22, a party of three men under the leadership of David T. Jones, temporarily attached to the Smithsonian Institution, was surveying, mapping, and testing the sites remaining within the upper Big Bend Reservoir. The results of the survey will be used as a basis for selecting the sites to be investigated during the next (and probably final) year of work within the reservoir.

On June 15, two field parties, one under the general direction of Robert W. Neuman, with field supervision by Oscar L. Mallory, and the other under Mallory's direction, began work in the Oahe Reservoir. The first, consisting of nine men, was excavating at the Stelzer site (39DW242) near Mobridge, S. Dak., continuing the excavations of 1963. The second party of eight resumed work at site 39DW231, a multicomponent, fortified village first tested last year. By the end of the fiscal year both groups had removed the overwinter slumpage and had begun the excavation of a number of habitation features.

A third party of 12 men, working under the direction of Dr. Alfred W. Bowers, began excavations in the Mobridge area of the Oahe Reservoir on June 17. The Bowers party was to complete the investigation of the Red Horse Hawk (39CO14) and Larson (39WW2) sites begun during earlier field seasons. At the end of the fiscal year the

fill had been removed from several houses and a large cut had been made across the defensive ditch.

A final field party of two men, under the direction of G. Hubert Smith, conducted a survey of historic sites in the Big Bend, Oahe, and Fort Randall Reservoirs from June 23 to 28. As was the case with the aboriginal sites, high water within the reservoirs has become a threat to previously undamaged historic sites. The Smith party examined a number of sites, made a photographic record of sites now destroyed or in the process of destruction, and secured data necessary for future work.

There were seven cooperating institutions working within the Missouri Basin at the end of the fiscal year. The St. Paul Science Museum completed a survey of the Bowman-Haley Reservoir of northwestern South Dakota and in late May and in early June began a shoreline reconnaissance of the Garrison Reservoir in North Dakota. In both instances the field parties were directed by Vernon R. Helmen. University of Missouri field parties, under the direction of Dr. Carl F. Chapman, were surveying and excavating in the Stockton and Kaysinger Bluff Reservoirs in Missouri, continuing the work of past seasons. University of Nebraska parties, directed by Dr. Preston Holder, were excavating in the Glen Elder and Milford Reservoirs of northwestern Kansas. A State University of South Dakota group, led by Dr. James H. Howard, was continuing investigations within the Lewis and Clark Lake area along the border of South Dakota and Nebraska. A field group of the State Historical Society of North Dakota, under the direction of Dr. Donald J. Lehmer, was excavating at the Fire Heart Creek Village (32SI2) in the Upper Oahe Reservoir of southern North Dakota. A field party of the Kansas State Historical Society, under the general direction of Thomas A. Witty, was excavating in the Council Grove Reservoir of eastern Kansas, and a field group from Iowa State University, directed by David Gradwohl, was excavating in the Red Rock Reservoir of central Iowa.

During the period that the Missouri Basin Project archeologists were not in the field, they were engaged in analyses of their materials and in laboratory and library research. They also prepared manuscripts of technical reports and wrote articles of a popular nature. In addition to the regular staff, Dr. Alfred W. Bowers, of the University of Idaho; Dr. William M. Bass, of the University of Kansas; and Dr. Elden Johnson, of the University of Minnesota, joined the Missouri Basin Project to complete short-term laboratory and field research assignments. Dr. Bowers again became a temporary staff member on June 17, and David T. Jones, West Nottingham Academy, Maryland, on June 22. Both were on duty through the end of the fiscal year.

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By the end of the fiscal year the Missouri Basin Chronology Program has been in operation 6½ years. The cooperation of other institutions and individuals within the anthropological profession continued as in the past. Dendrochronological research has been much reduced because personnel were lacking. However, some new material was studied and plans have been completed for a renewed attack during the coming year. The carbon-14 section continued to progress with the addition of 15 new dates. Eight dates, from three sites, apply to villages of both the Middle Missouri and Coalescent Tradition of the Big Bend Reservoir, central South Dakota. Three additional dates derive from two sites, a group of burial mounds and a late fortified village, in the Oahe Reservoir of northern South Dakota. The remainder date various preceramic horizons from a stratified site in the Yellowtail Reservoir, Mont. The Missouri Basin Chronology Program continued to use the facilities of Isotopes, Inc., as well as those of the division of radiation and organisms of the Smithsonian Institution.

The laboratory and office staff of the Missouri Basin Project devoted most of its effort during the year to the processing of materials for study, preparing specimen records, typing, filing, and illustrating records and manuscripts. The accomplishments of the laboratory and office staff are listed in tables 1 and 2.

During the first quarter, Dr. Robert L. Stephenson, chief, devoted most of his time to the overall management of the Missouri Basin Project, including the office and laboratory in Lincoln and the several field parties. He devoted a portion of his time to laboratory analysis of materials he had excavated in previous years. His report, "The Accokeek Creek Site: A Middle Atlantic Seaboard Culture Sequence," was published by the University of Michigan, and he submitted several book reviews for publication. Until September 30, when he assumed his new duties as assistant director of the River Basin Surveys in Washington, D.C., he continued to serve as chairman of the Missouri Basin Chronology Program, as assistant editor of "Current Research" in the Plains area for *American Antiquity*, and as editor of the *Plains Anthropologist*.

Dr. Warren W. Caldwell worked in the laboratory through the first quarter, analyzing materials excavated in the previous two field seasons. A substantial portion of a manuscript entitled, "The Grand Detour Phase: Early Village Sites in the Big Bend Reservoir, South Dakota" (with Richard E. Jensen) was completed by September 30, at which time Dr. Caldwell assumed the duties of Chief of the Missouri Basin Project. During the remainder of the year, Dr. Caldwell devoted a substantial portion of his time to the management of the Project, to budgetary matters, and to the planning of the forthcoming field

TABLE 1.—*Specimens processed July 1, 1963, through June 30, 1964* [1]

Reservoir	Number of sites	Catalog numbers assigned	Number of specimens processed
Almena	1	1	2
Angus	2	19	60
Big Bend	18	5, 008	39, 993
Fort Scott	6	67	67
Garnett	7	62	64
Garrison Diversion Project	7	32	166
Gavins Point	1	66	527
James Diversion Project	1	11	22
Oahe	18	5, 852	29, 141
Pony Creek	14	1, 025	4, 590
Round Mound	2	13	16
Tuttle Creek	9	2, 806	15, 943
Yellowtail	22	1, 870	5, 072
Sites not in a reservoir	2	22	68
Total	110	16, 854	95, 731
Collections not assigned site numbers	6	7	20
Grand total	116	16, 861	95, 751

[1] As of June 30, 1964, the Missouri Basin Project has cataloged 1,485,104 specimens from 2,250 numbered sites and 66 collections not assigned site numbers.

Specimens restored included 2 pottery vessels and 5 vessel sections.

Specimens donated to the Missouri Basin Project included ca. 100 rim sherds and 1 vessel section from the Swan Creek site (39WW7) (donated by the South Dakota State Museum, University of South Dakota), 15 projectile points from the Rinehardt Buffalo Kill No. 2 (24LT00) (donated by Carle Leavitt of Conrad, Mont.), a surface collection from 39YK203 (donated by George Kostal and Ansel Petersen, civil engineers at the Gavins Point Dam), and a collection of pottery sherds from the Southwest (donated by Dr. Frank H. H. Roberts).

Specimens collected at Fort Laramie, Wyo., were cleaned but not cataloged by the Missouri Basin Project.

TABLE 2.—*Record material processed, July 1, 1963, through June 30, 1964*

MISSOURI BASIN PROJECT

Reflex copies of records	6, 563
Photographic negatives made	1, 299
Photographic prints made	7, 169
Photographic prints mounted and filled	4, 625
Transparencies mounted in glass	1, 507
Kodachrome pictures taken in lab	180
Cartographic tracings and drawings	50
Illustrations	74
Lettering of plates	49
Profiles drawn	14
Plate layouts made for manuscripts	64

season. In addition, he continued to work with Jensen on the "Grand Detour Phase" manuscript and prepared a monograph, "Archeological Salvage Investigations in the Hells Canyon area, Snake River, Oregon and Idaho," for publication by the Bureau of American Ethnology. During the year several papers of which Dr. Caldwell was author or co-author were published. These include "Excavations in the Lower Big Bend Reservoir, South Dakota," *Plains Anthropologist*, vol. 8, No. 20, p. 118; "Taxonomy Revisited," *Plains Anthropologist*, vol. 8, No. 20, pp. 84–85; (with G. Hubert Smith) *The Oahe Reservoir: Archeology, Geology, History*, U.S. Army Corps of Engineers, Omaha, pp. 1–44; (with Lee G. Madison and Bernard Golden) "Archeological Investigations at the Hickey Brothers Site (39LM4), Big Bend Reservoir, Lyman County, South Dakota," *River Basin Surveys Papers No. 36, Bureau of American Ethnology, Bulletin 189*, pp. 267–290; "Fortified Villages in the Northern Plains," *Plains Anthropologist*, vol. 9, No. 23, pp. 1–7.

At the 20½ Plains Conference held at Pierre, S. Dak., on July 20 Dr. Caldwell spoke on the problem of the firearms trade and Plains archeology. He also attended the Governors' Conference for the Lewis and Clark Reenactment Pageant at Camp Ashland on November 19 and presented a brief statement regarding the potential contribution of the Missouri Basin Project to region-wide recreational planning. On September 6 and 7 he participated in the joint Plains-Pecos Conference at Fort Burgwin, near Taos, N. Mex., and spoke on "The LaRoche Problem." He also attended the meetings of the Committee for the Recovery of Archeological Remains, in Washington, D.C., on February 12 and 13; the 74th Meeting of the Nebraska Academy of Sciences, Lincoln, May 1 and 2; and the annual meeting of the Montana Archeological Society, Havre, May 16 and 17. At the last-named he presented a paper, "The Northwestern Plains and the Missouri River Basin," and participated in a panel discussion of Plains archeological problems. He continued to serve as dendrochronology chairman of the Missouri Basin Chronology Program and, until December, as contributing editor for reviews for the *Plains Anthropologist*. As of that time he replaced Dr. Stephenson as editor of the journal and continued in that capacity through the year. Dr. Caldwell participated in the Visiting Scientist Program of the Nebraska Academy of Sciences, speaking before student groups at Utica, Nebr., on January 8. In addition, he presented talks or lectures to eight civic and university groups. In October he was named as one of the organizers for the Plains Field Conference preceding the 1965 INQUA meeting at Boulder, Colo. During the period of September to June he continued to serve, on annual leave, as part-time assistant professor of anthropology at the University of Ne-

braska, and in January he was elected to the Graduate College. At the end of the year Dr. Caldwell was in the Lincoln office continuing his administrative duties.

Lionel A. Brown, archeologist, when not in the field, devoted his time to laboratory study and reporting of materials from his 1962 and 1963 surveys and excavations. In addition, he assumed responsibility for a portion of the backlog of unreported sites contained in the Missouri Basin Project files. During the spring Mr. Brown made a preliminary analysis of the specimens excavated from the Chapelle Creek Village (39HU60) during the 1963 season as a guide to further work at the site. A manuscript entitled "Archeological Investigations in the Lower Yellowtail Reservoir, Montana," was rewritten in second draft. Another, a comprehensive report, "Archeological Investigations in the Pony Creek Watershed, Iowa," was in rough draft form, and "The Gillette Site (39ST23), Oahe Reservoir, South Dakota," was in near final form. During the year his survey report, "An Appraisal of the Archeological and Paleontological Resources of Six Reservoir Areas in Kansas and Nebraska," was issued for limited distribution. Two brief field reports, "Survey of the Pony Creek Watershed, Iowa," and "Archeology of the Lower Yellowtail Reservoir, Montana," (*Plains Anthropologist*, vol. 8, No. 20, p. 117, and vol. 8, No. 20, p. 119, respectively) and two articles "The Fort Smith Medicine Wheel, Montana" and "A Crow Lodge Frame" were published in the *Plains Anthropologist* (vol. 8, No. 22, pp. 225–230, 273–274, respectively). Another, "The Lungren Site: An Archaic Manifestation in Southeastern Iowa," appeared in abstract in the *Proceedings of the 74th Annual Meeting of the Nebraska Academy of Sciences*, Lincoln (p. 3). On May 24, at the annual meeting of the Iowa Archeological Society, he presented a summary of recent work in southwestern Iowa, and on the 25th he made a brief survey of sites in the Rathbun Reservoir of south-central Iowa. At the end of the year Mr. Brown was again in the field engaged in archeological excavations at the Chapelle Creek site, S. Dak.

John J. Hoffman, archeologist, when not in the field, devoted most of his efforts to the laboratory analysis and preparation of reports, based upon materials excavated during his field work of the past two years. In addition, he has undertaken a reanalysis of certain pottery collections that have been previously described in the literature to bring them into accord with current concepts. A large site report, "Molstad Village: A Fortified Site in the Oahe Reservoir, South Dakota," was completed in first draft, and a shorter paper reexamining a number of late prehistoric and early historic sites in the Mobridge area, South Dakota, and an analysis of materials from the La Roche sites are under way. Previous studies of Mr. Hoffman's, published

during the year, include "Temporal Ordering and the Chouteau Aspect," *Plains Anthropologist*, vol. 8, No. 20, pp. 91–97; "Prehistoric Houses Along the Middle Missouri River," *Progress*, Oct.–Dec., 1963, *Missouri Basin Field Committee*, Billings, pp. 43–57; "Investigation of the Swift Bird House (39DW233) in the Oahe Reservoir, South Dakota," *Plains Anthropologist*, vol. 8, No. 22, pp. 249–256; a field report, "Excavations at Molstad Village in the Oahe Reservoir," *Plains Anthropologist*, vol. 8, No. 20, pp. 118–119; and two short book reviews also published in the *Plains Anthropologist.*

Mr. Hoffman served as chairman of the 20½ Plains Conference at Pierre on July 20, which he reported briefly in the *Plains Anthropologist*, vol. 8, No. 22, p. 262. He also participated in the joint Plains-Pecos meeting at Taos, N. Mex., September 6–7, where he presented a paper entitled, "La Roche: Some New Data," and attended the annual meeting of the Montana Archeological Society at Havre, May 16 and 17. He also spoke before several school and civic groups in Nebraska and Iowa. At the end of the year Mr. Hoffman was again in the field engaged in archeological excavations in the Big Bend Reservoir of South Dakota.

Wilfred M. Husted, archeologist, when not in the field, prepared reports, based upon materials excavated during his 1963 field investigations, and continued to work on the backlog of site collections from the Missouri Basin Project files. A manuscript report entitled "Archeological Test Excavations at Fort Laramie National Historic Site, Wyoming, 1963" was completed and accepted by the U.S. National Park Service, Midwest Region. A final draft of "The Bice Site (39LM31) and the Clarkstown Site (39LM47): Salvage Excavations in the Fort Randall Reservoir, South Dakota" was completed, and major drafts of three as yet untitled reports dealing with sites in the Big Bend and Fort Randall Reservoirs are substantially finished. Mr. Husted submitted two papers, "Early Occupation of the Colorado Front Range" and "Pueblo Pottery from Northern Colorado," for publication, and two short reports, "Investigations in the Upper Yellowtail Reservoir, Montana and Wyoming" and "A Rock Alignment in the Colorado Front Range," were published in the *Plains Anthropologist* (vol. 8, No. 20, p. 119, and vol. 8, No. 22, pp. 221–224, respectively). At the end of the year he was in the field excavating sites in the Yellowtail Reservoir of Wyoming and Montana.

Richard E. Jensen, archeologist, when not in the field, worked primarily on the analysis and reporting of site collections excavated by staff members in previous years, but following the death of Dean E. Clark, laboratory supervisor, he assumed direction of the processing and cataloging staff in addition to his regular duties. He cooperated with Dr. Caldwell in the preparation of a major study entitled, "The

Grand Detour Phase: Early Village Sites in the Big Bend Reservoir, South Dakota," and completed a first draft of "The Peterson Site (39LM215), An Earth Lodge Village in the Big Bend Reservoir." A study concerned with recent work in the Big Bend Reservoir, "A Temporal Ordering of Several Rectangular House Occupations in Central South Dakota" (abstract), was published in the *Proceedings of the 74th Annual Meeting of the Nebraska Academy of Sciences*, Lincoln, 1964, p. 4. On July 20, Mr. Jensen attended the 20½ Plains Conference at Pierre, S. Dak., where he reported the progress of his fieldwork. He also participated in the Plains-Pecos meeting at Taos, N. Mex., presenting a brief paper entitled, "Notes on the Archeology of the Big Bend Area." At the end of the year he was in the field excavating at the Sommers site in the Big Bend Reservoir.

Oscar L. Mallory, archeologist, when not in the field, continued the analysis and reporting of materials that he excavated or collected in previous field seasons. A reconnaissance report, "An Archeological Appraisal of the Missouri Breaks Region in Montana," was completed and issued for limited distribution, and a short note entitled "Survey of the Missouri Breaks Region, Montana," summarizing the work, was published in the *Plains Anthropologist* (vol. 8, No. 20, p. 120). In addition, Mr. Mallory completed a detailed study of the artifacts from the Mouat Cliff Burials (24TE401), Mont., which will be a part of a larger study of the excavations carried out by members of the Billings Archeological Society. Another manuscript concerned with a group of sites in the vicinity of the Moreau River, Oahe Reservoir, is well under way. At the end of the year Mr. Mallory was in the field excavating sites in the Oahe Reservoir.

Robert W. Neuman, archeologist, when not in the field, devoted most of his time to the analysis and reporting of data resulting from his excavations during previous field seasons. He has begun a major monograph concerned with early burial mound complexes in the northern Plains. He has also completed an article entitled "Projectile Points from Preceramic Occupations near Fort Thompson, South Dakota," which has been accepted by the *Plains Anthropologist*, and, in addition, a number of Mr. Neuman's research papers, most of which were written during the current year, were published. These include: "Check-stamped Pottery on the Northern and Central Great Plains," *American Antiquity*, vol. 29, No. 1, 1963, pp. 17–26; "Field Work in Dewey County, South Dakota, Oahe Reservoir Area," *Plains Anthropologist*, vol. 8, No. 20, pp. 121–122; "Archeological Salvage Investigations in the Lovewell Reservoir Area, Kansas," *River Basin Surveys Papers No. 32, Bureau of American Ethnology Bulletin 185*, pp. 257–306; (with Carl R. Kendle and Larry A. Witt) "Prehistoric Artifacts from the Little Nemaha River Drainage, Otoe County, Nebraska,"

Plains Anthropologist, vol. 9, No. 23, pp. 22–28; "The Good Soldier Site (39LM238), Big Bend Reservoir, Lyman County, South Dakota," *River Basin Surveys Papers No. 37*, *Bureau of American Ethnology Bulletin 189*, pp. 291–318.

Mr. Neuman attended the 20½ Plains Conference in Pierre, S. Dak., July 20, the annual meeting of the Nebraska Academy of Sciences, Lincoln, May 1 and 2, and the meeting of the Society for American Archeology, Chapel Hill, N.C., May 7–9, where he presented a paper on "A Woodland Camp and Burial Mound Complex in Dewey County, South Dakota." He continued to serve as chairman of the Radiocarbon Section of the Missouri Basin Chronolgy Program, was appointed assistant editor for current research (Plains area) for *American Antiquity*, and contributing editor for Plains facts for the *Plains Anthropologist*. Mr. Neuman participated in the Visiting Scientist Program of the Nebraska Academy of Sciences, speaking before school groups at Eddyville, Nebr., and he also presented an illustrated talk to the National Professional Geographical Fraternity at the University of Nebraska. At the end of the year Mr. Neuman was at work in the Lincoln laboratory.

G. Hubert Smith, archeologist, when not in the field, was concerned with the preparation of reports based upon his previous work at several historic sites. By the end of the year he had completed a comprehensive report on investigations by the Missouri Basin Project and the State Historical Society of North Dakota at the sites of Like-A-Fishhook Village and Fort Berthold I and II (32ML2), in the Garrison Reservoir area, North Dakota. In addition, he had made substantial progress on reports of excavations of Fort George (39ST202) and 39HU301, in the Big Bend Reservoir of South Dakota and had begun preparation (with Caldwell and others) of the booklet "The Big Bend Reservoir: Archeology and History," to be published by the U.S. Army Corps of Engineers. An article written by Mr. Smith, "Archeological Explorations at Fort McHenry, 1958," was published in the *Maryland Historical Magazine* (vol. 58, No. 3, pp. 247–250), and a brief note, "Excavations at Fort George, South Dakota," appeared in the *Plains Anthropologist* (vol. 8, No. 20, p. 122).

On July 20 he took part in discussions of northern Plains ethnohistory, at the 20½ Plains Conference at Pierre, S. Dak. At the Plains-Pecos meeting at Taos, N. Mex., on September 6 and 7, he reported recent investigations at historic sites within the Missouri Basin reservoir areas. During the period October 24–30 he examined historic sites in Missouri at the request of Dr. Carl H. Chapman and other University of Missouri staff members. On October 28 Mr. Smith addressed the annual meeting of the Missouri Archeological Society at Columbia, Mo., and that evening spoke before the Big Bend chapter of the

Society at Marshall, Mo. On April 10, he presented an illustrated lecture, "Archeological Salvage within the Missouri Basin," before the annual meeting of the Minnehaha County Historical Society at Sioux Falls, S. Dak., and on May 2 he read a paper entitled "The Viking Site in Newfoundland" before the anthropological section of the Nebraska Academy of Sciences (published in abstract in the *Proceedings of the 74th Annual Meeting of the Nebraska Academy of Sciences*, Lincoln, p. 5). In April Mr. Smith became contributing editor for reviews for the *Plains Anthropologist.* At the end of the year he was at work in the Lincoln Laboratory of the Missouri Basin Project.

Virginia.—Carl F. Miller, at the beginning of the fiscal year, had an excavation crew at work on the Hales Ford site (44FR14) in the Smith Mountain Reservoir area near Rocky Mount in southern Virginia. He completed the work at this site on July 2, having excavated 144 archeological features and recovered various tool types, burial patterns and offerings, and, of particular interest, a series of bone flutes that suggested much in the way of social life of these Early to Middle Woodland Indians. The power screen was used during these excavations, making possible a nearly complete recovery of the cultural remains.

Mr. Miller and his crew of five men moved to the Booth Farm site (44FR15) on July 2, and between then and July 28, when the field work ended, they excavated 202 archeological features. A number of Savannah projectile points of the Late Archaic and Early Woodland Periods were found lying on sterile hardpan at the base of the site and in association with several random post molds. Noteworthy were the remains of 70 feet of stockade found at the south edge of the site. In this stockade, posts had been placed at intervals and reinforced with rocks in the postholes. Wooden stringers had connected the vertical posts, and to these had been attached other posts, much as a modern fence would be built.

Idaho-Oregon.—Under an agreement with the Smithsonian Institution, the Idaho State University Museum continued the work on the Hells Canyon Reservoir material that was excavated during the latter part of last fiscal year. The project, under the direction of Dr. Earl H. Swanson, director of the Museum, was continued by Max G. Pavesic, a graduate student at the University of Colorado. Work was confined largely to laboratory analysis of the excavated material, rechecking a few of the field locations, and preparation of the report.

ARCHIVES

Mrs. Margaret C. Blaker continued her duties as archivist, assisted until August 1 by Regina M. Solzbacher and for the remainder of the fiscal year by Margaret V. Lee.

An extensive series of photographic prints and lantern slides, made

in the 1880's and 1890's and showing Indian students at Hampton Institute, as well as views made on a number of western reservations, was borrowed from the Huntington Memorial Library of Hampton Institute, Hampton, Va. Approximately 400 copy negatives were made from this loan collection and are now in the Bureau's active files.

Over 150 photographs of Osage Indians, including many full-length portraits of individuals in native costume taken in the 1880's and 1890's in the studios of G. W. Parsons and J. M. Fowler of Pawhuska, Okla., were received on loan from the Osage Tribal Museum, Pawhuska, Okla. in May and are currently being copied.

Approximately 100 glass plate negatives exposed by Dr. Robert Charles Gebhardt in the period 1900–1907, showing Indians on the streets of Black River Ralls, Wis., and their homes and burial grounds near the cranberry marshes outside the town, were acquired from the photographer's son, Paul Gebhardt of Towson, Md.

Thirty photographs of Florida Seminole Indians, and Seminole camps, boats, and agricultural scenes, made in 1910–11 by Lorenzo D. Creel, special agent, were copied from Creel's manuscript report in the National Archives.

Thirteen studio and outdoor photographs of Winnebago Indians taken in the period from the 1870's to about 1900 by H. H. Bennett, pioneer photographer of Kilbourn, Wis., now Wisconsin Dells, were acquired from the Bennett Studio in Wisconsin Dells. This studio and its files of glass negatives of persons, places, and events in the Wisconsin Dells area in the period 1865 to 1907 is now maintained by the photographer's daughters, Miss Miriam Bennett and Mrs. Ruth Bennett Dyer.

Three original prints from negatives made about 1899 in the vicinity of Chadron, Nebr., by Ed Edson were received from Dr. R. W. Breckinridge, through the Lincoln, Nebr., office of the River Basin Surveys. They are portraits of Red Cloud and Little Wound, Oglala Dakotas, and a view of a Sioux camp near Chadron, Nebr.

Individual portraits of five Sioux Indians, taken in 1899 by Robert Gish Parker of Chicago, were donated by a nephew of the photographer, Mr. Leslie B. Taylor of Miami, Fla. The photographs include a portrait of the famous show Indian, Iron Tail.

Four negatives made by Dr. Francis Harper on the Poosepatuck Reservation, Mastic, Long Island, in 1909 were donated by Dr. Harper and filed with related negatives previously donated by him.

A group of 10 photographic reproductions on postcards were donated by Philip Sampson of Arlington, Va. They included a full-length portrait as well as front and profile bust portraits of the Kaw (Kansa) chief Washunga, taken about 1880.

Eugene Heflin of Reedsport, Oreg., submitted an account of his

attempts to salvage skeletons and artifacts from the site of the historic village of Shet-le-shin, on Pistol River, southwest Oregon. This site has now been destroyed by road construction. A microfilm copy of Mr. Heflin's account, which included news clippings, photographs and pen-and-ink drawings, was made and the original returned to him.

A Micmac vocabulary and grammatical notes recorded by P. L. Muschamp while he was a graduate student at Yale University were deposited by Mr. Muschamp. Unfortunately Mr. Muschamp's more extensive notes on his Micmac fieldwork had been lost in a fire that destroyed his home a number of years ago. These notes are on 3×5″ slips and occupy one file box.

EDITORIAL WORK AND PUBLICATIONS

The editorial work of the Bureau continued during the year under the immediate direction of Mrs. Eloise B. Edelen, assisted by Mrs. Phyllis W. Prescott and Miss Susan Colby. The following publications were issued:

Eightieth Annual Report of the Bureau of American Ethnology, 1962–1963, ii+34 pp., 2 pls. 1964.

Bulletin 178. Index to Bulletins 1–100 of the Bureau of American Ethnology, with index to contributions to North American Ethnology, introductions, and miscellaneous publications, by Biren Bonnerjea. vi+726 pp. 1963.

Bulletin 186. Anthropological Papers, Nos. 63–67. iv+310 pp., 60 pls., 35 figs., 2 maps. 1963.

- No. 63. Tarqui, an early site in Manabí Province, Ecuador, by Matthew W. and Marion Stirling.
- No. 64. Blackfoot Indian pipes and pipemaking, by John C. Ewers.
- No. 65. The Warihio Indians of Sonora-Chihuahua: An ethnographic survey, by Howard Scott Gentry.
- No. 66. The Yaqui deer dance: A study in cultural change, by Carleton Stafford Wilder.
- No. 67. Chippewa mat-weaving techniques, by Karen Daniels Petersen.

Bulletin 187. Iroquois music and dance: Ceremonial arts of two Seneca Longhouses, by Gertrude P. Kurath. xvi+268 pp., 3 pls., 164 figs. 1964.

Bulletin 189. River Basin Surveys Papers, Nos. 33–38, Frank H. H. Roberts, Jr., editor. xiv+406 pp., 58 pls., 66 figs., 13 maps. 1964.

- No. 33. The Paul Brave site (32SI4), Oahe Reservoir area, North Dakota, by W. Raymond Wood and Alan A. Woolworth.
- No. 34. The Demery site (39CO1), Oahe Reservoir area, South Dakota, by Alan R. Woolworth and W. Raymond Wood.
- No. 35. Archeological investigations at the Hosterman site (39PO7), Oahe Rerservoir area, Potter County, South Dakota, 1956, by Carl F. Miller.
- No. 36. Archeological investigations at the Hickey Brothers site (39LM4), Big Bend Reservoir, Lyman County, South Dakota, by Warren W. Caldwell, Lee G. Madison, and Bernard Golden.
- No. 37. The Good Soldier site (39LM38), Big Bend Reservoir, Lyman County, South Dakota, by Robert W. Neuman.
- No. 38. Archeological investigations in the Toronto Reservoir area, Kansas, by James H. Howard.

Bulletin 190. An ethnography of the Huron Indians, 1615–1649, by Elisabeth Tooker. iv+184 pp. 1964.

Publications distributed totaled 35,314 as compared with 17,722 for the fiscal year 1963.

ILLUSTRATIONS

Throughout the year, E. G. Schumacher, the staff artist for the Bureau of American Ethnology, prepared and executed many varied illustrations in the fields of ethnology and archeology, to appear in Bureau publications. The bulk of the art work concerned the retouching and/or restoration and assembling of photographs, the drawing of maps, charts, diagrams, graphs, and sundry text figures. Mr. Schumacher also performed miscellaneous assignments for other units of the Smithsonian Institution, including the Editorial and Publications Division.

MISCELLANEOUS

Dr. M. W. Stirling and Sister Inez Hilger continued as research associates of the Bureau. Dr. A. J. Waring, formerly research associate, died on March 21, 1964. Mrs. Phyllis W. Prescott, who had assisted in editing many of the Bureau publications, died on June 12, 1964, after a brief illness.

The Bureau continued its extensive service to scholars, teachers, students, and the interested layman in providing information on technical questions, bibliographies, and leaflets on special topics relating to the American Indian.

Specialists on the Bureau staff identified and supplied information on many specimens, both ethnological and archeological, which were brought in or received by mail.

Respectfully submitted.

HENRY B. COLLINS, *Acting Director.*

S. DILLON RIPLEY,
Secretary, Smithsonian Institution.

Report on the National Zoological Park

SIR: I have the honor to submit the following report on the activities of the National Zoological Park for the fiscal year ended June 30, 1964:

BIRTHS

One of the most beautiful animals in the Zoo is Mohini of Rewa, the so-called white tiger. With her cream-colored coat, striped with varying hues of gray to black, her ice-blue eyes, her great size and majestic mien, she has been an extremely popular exhibit since her arrival in 1960. Her mate, Samson, is a normal-colored tiger but comes from the same strain and hence carries the genes for whiteness. Mated to a white female, he could be expected to sire white cubs.

On January 6, 1964, three young were born to the pair; one white, the other two orange. Through the courtesy of Metromedia, a closed-circuit television was installed, and the actual birth of the cubs was witnessed by members of the Zoo staff on a monitor placed in the vestibule of the lion house. Until the cubs were 6 weeks old the lion house was closed to the public. Zoo visitors could, however, watch the little family on either one of two television screens. Mohini proved to be an exceptional mother; she took the greatest care of her cubs, and all three, now weaned, are thriving. When they were first put on exhibition they were so popular that it was necessary to put a sign on the cage asking visitors to move on and let others enjoy the scene; some people actually arrived in the morning and spent the entire day standing in front of the cage until the building closed in the evening. A film of the birth, combined with a film made at the palace of the Maharajah of Rewa in India, was shown on a half-hour nationwide television program.

For many years, the National Zoological Park was famous for its success in breeding pygmy hippopotamuses. Then the old male died, and it was several years before a replacement for him could be secured. In 1960 President William V. S. Tubman of Liberia donated a male pygmy hippo, which has now sired seven offspring, three of them within the past year. Two Nile hippopotamuses were also born at the National Zoo this year.

On September 9, 1961, the first gorilla to be bred and born at the National Zoological Park arrived, the offspring of Moka and

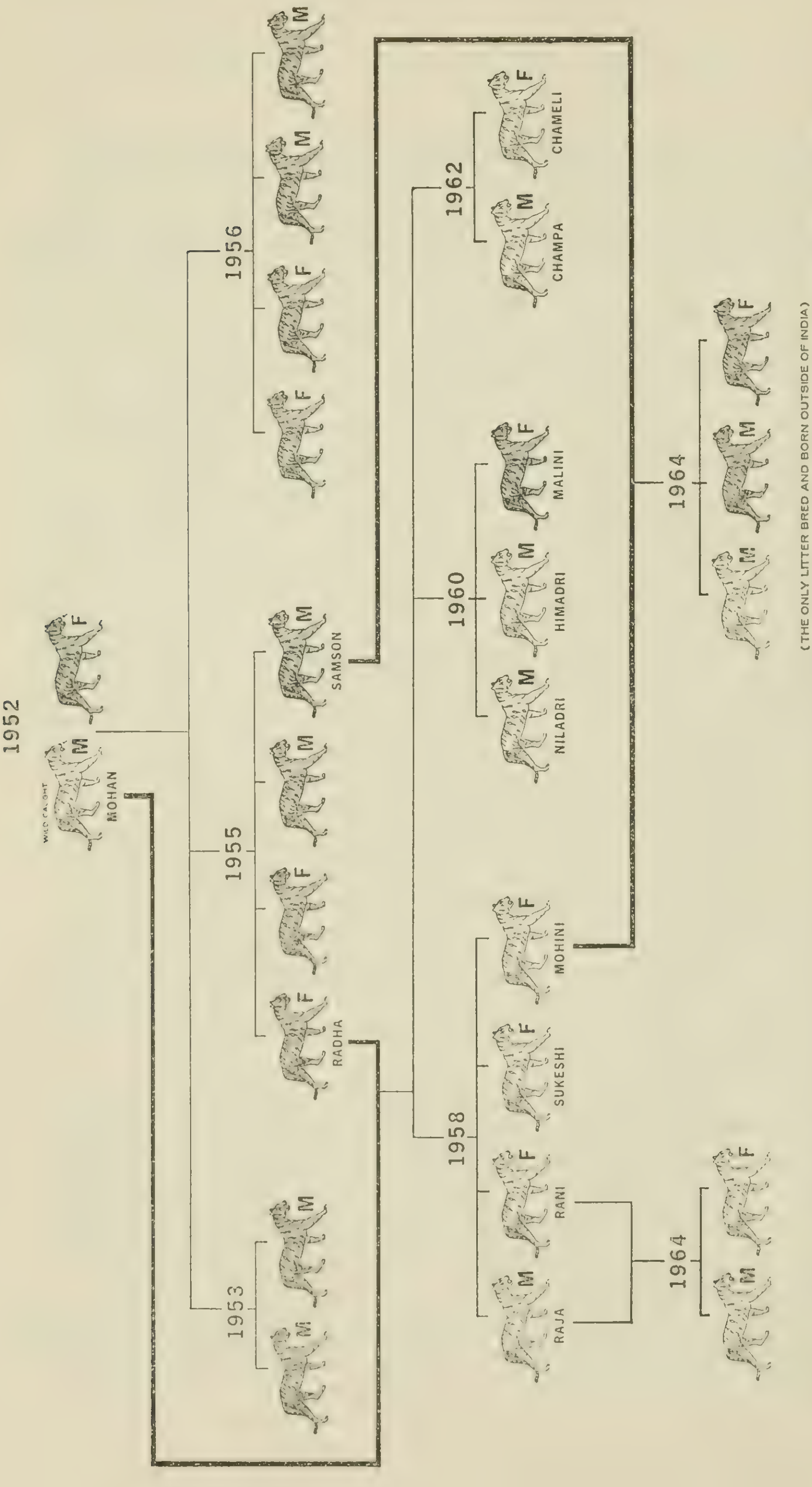

FIG. 1.—Family tree of all the white tigers in captivity on June 30, 1964, shows relationship of the National Zoological Park's Mohini Rewa and her mate, Samson. The white cub born on January 6, 1964, in Mohini's first litter is the first white tiger born outside of India. M=male; F=female.

Nikumba, lowland gorillas. The baby was named Tomoka and was successfully reared by the wife of Keeper Bernard M. Gallagher. Moka's first pregnancy was carefully watched, and the birth of the baby was eagerly anticipated. After her pregnancy, like some human mothers, she began to put on weight, and although her diet was carefully supervised she continued to gain. This, and the fact that the male gorilla suffered an attack of paralysis in June 1963 (see p. 143), account for her second baby, Leonard, arriving as something of a surprise package on January 10, 1964. Leonard, like his brother, is being raised in Keeper Gallagher's home and gives every evidence of being a normal, healthy young gorilla.

Four more calves were born to the Dorcas gazelles, increasing the number of these graceful little animals to a herd of eight. The original pair were gifts from President Habib Bourguiba of Tunisia in 1960.

Other interesting additions were two hybrids between a male cottontop marmoset (*Saguinus oedipus*) and a female red-handed tamarin (*S. midas*), born on February 19. The babies closely resemble their mother, lacking the white pompadour of the cottontop.

Following the procedure of previous years, all births and hatchings are listed below, whether or not the young were successfully reared. In many instances, the record of animals having bred in captivity is of interest.

MAMMALS

Common name	Number	Common name	Number
Rat kangaroo	1	Leopard	**3
Vampire bat	2	Lion	3
Ring-tailed lemur	1	Bengal tiger	3
Squirrel monkey	1	Sea-lion	2
Black spider monkey	2	Rock hyrax	2
Hybrid marmoset	2	Grant's zebra	3
Rhesus monkey	1	Brazilian tapir	*1
Barbary ape	2, *1	Collared peccary	5
Sooty mangabey	1	Nile hippopotamus	2
Chimpanzee	1	Pygmy hippopotamus	3
Lowland gorilla	1	Llama	4
Two-toed sloth	1	White fallow deer	2
Prairie-dogs	6	Axis deer	4
Egyptian spiny mouse	10	Red deer	2
Patagonian cavy	4, *2	Sika deer	1
Hairy-rumped agouti	3	White-tailed deer	1
Timber wolf	1	Reindeer	3, *1
Hybrid fox	1	Caribou × reindeer	1
European brown bear	3	Cape buffalo	1
Hybrid bear	1	Brindled gnu	2
Grizzly bear	1	Dorcas gazelle	4
Neumann's genet	**1	African pygmy goat	1
Bobcat	1	Aoudad	1
Black leopard	2	Big-horn sheep	1

*Stillborn.
**Second litter destroyed by mother.

BIRDS

Black-crowned night heron	3	Mallard duck	110
Crested screamer	1	Peafowl	1
Black swan	4	Nanday parrot	3
Wood duck	54	Formosan red-billed pie	2

REPTILES

Snapping turtle	21	Tokay gecko	1
Box turtle	7	African spiny lizard	2
Eastern box turtle	6	Pilot black snake	9
Red-lined turtle	1	Tessellated snake	1
Red-bellied turtle	1	Cantil	26
Red-eared turtle	1		

FISHES

Red swordtails	40

GIFTS

More than a year ago the Government of Assam, India, offered the National Zoological Park a female rhinoceros as a mate for Tarun, the male rhino that came to the Zoo in May 1960. An adult female was secured from the Kazirangi Game Reserve, and negotiations began to transport her from India to Washington. Then it was discovered that "Deepali" was pregnant, and all plans for her trip to the United States were held in abeyance until her calf was born. In April 1963 she produced a female calf, subsequently named Rajkumari, and it was necessary to wait until the young one was weaned. In October Associate Director J. Lear Grimmer and Mrs. Grimmer went to India to arrange transportation for the huge animal. They found, to their delight, that the Indian Government was including the baby in the generous gift to the United States. Crates were built under Mr. Grimmer's supervision, and both animals were brought to the zoo in Calcutta. No commercial airline could handle the shipment (Deepali, crated, weighed 4,000 pounds). Fortunately a number of planes from the American Air Force were in India at the time, participating in joint Indo-Anglo-American air exercises, and through the good offices of the then Vice President, Lyndon B. Johnson, who was a Regent of the Smithsonian Institution, and Air Force Chief of Staff Curtis LeMay, it was possible to load both animals on a C–130 transport. The animals arrived December 17, and were unloaded at the elephant house at dusk. Only 11 days later Deepali succumbed to an acute attack of gastroenteritis. This was a tragic loss for the Zoo, but Rajkumari (the name means "princess") has adapted nicely to the Zoo regime, is eating well, gaining weight, and of course is the most valuable single acquisition made by the Zoo during the past year.

On February 12 the director left for Indonesia with gifts of whis-

Caiman lizard (*Dracaena guianensis*) currently at the National Zoological Park. This unusual lizard is fed clams oysters, lobster tails, snails, and fish.

Female Komodo dragon (*Varanus komodoensis*) in her outdoor summer enclosure. National Zoological Park.

The rare and vanishing Texas red wolf (*Canis niger rufus*). This female was acquired on November 19, 1958, as a 6-month-old pup. National Zoological Park.

One of the rarest animals in the National Zoological Park's collection, the South American round-eared dog (*Atelocinus microtis*).

Mohini Rewa and 2-month-old son, the first white tiger bred and born outside of India. National Zoological Park. Wide World Photos.

Hybrid marmosets, born February 19, 1964, to a female red-handed marmoset (*Saguinus midas*) and male cottontop (*Saguinus oedipus*). National Zoological Park.

Leonard, second lowland gorilla bred and born at the National Zoological Park, at 6 months of age.

Rajkumari, young female Indian one-horned rhinoceros (*Rhinoceros unicornis*). National Zoological Park.

tling swans, ducks, and geese from Attorney General Robert Kennedy to President Sukarno of Indonesia. While there he accepted a most generous gift from the Government of Indonesia of a pair of the giant monitor lizards found on a few small islands in Indonesia and known as Komodo dragons. The male was nearly 9 feet long and weighed approximately 200 pounds; the female was about half that size. Again, the Zoo was most unfortunate, as the big male, a truly impressive specimen, died of systematic amebiasis on June 1, after only 12 weeks and 4 days on exhibition at the Park. The female has the same infestation with amebae, and every effort is being made to cure her, as she is the only one of this species in the United States at the present time.

Space does not permit listing all gifts received in the course of the year, but the following are of interest:

Allan, Karen, Fairfax County, Va., brush-tailed porcupine.

Amis, Mrs. Esther V., Washington, D.C., Patas monkey.

Birch, Mrs. H. M., Bethesda, Md., lesser hill mynah.

Chester Zoo, Chester, England, 2 axolotls (white phase).

Cochran, Dr. Doris, Washington, D.C., 5 tropical American turtles of 2 species.

Collette, Mrs. B. B., Alexandria, Va., sooty mangabey.

DesPres, Mrs. Helen, Monrovia, Liberia, Maxwell's duiker.

Dietlein, Lt. Donald R., Alameda, Calif., Galápagos tortoise, sulphur-breasted toucan.

Godet, Dr. René, Dakar, Senegal, lungfish.

Greenhall, Arthur, Washington, D.C., 4 spear-nosed bats, 8 vampire bats.

Greeson's Flying Squirrel Ranch, Arlington, Va., southern fox squirrel.

Harding, Grayson E., New York, N.Y., kura kura turtle, Amazon spotted turtle, red-faced turtle, chicken turtle, southern soft-shelled turtle, diamond-back terrapin.

Harris, Lester E., Takoma Park, Md., 6 timber rattlesnakes, 10 fer-de-lance.

Houston, Robert, Arlington, Va., Swan Island iguana.

Keegan, Lt. Col. Hugh L., U.S. Army Medical Command, Japan, 5 rat snakes of 4 species, Dinodon, 2 many-banded kraits, 2 palm vipers, 3 Ryukyu green snakes, Japanese water snake, Japanese pit viper, 4 habus of 3 species, 3 Erabu sea snakes.

Kennedy, Robert F., McLean, Va., 2 Geoffroy's marmosets.

Klikna, Mrs. Vincent, Falls Church, Va., 5 chinchillas.

Kuntz, Dr. R. E., Washington, D.C., 2 axolotls.

Marcus, Dr. Leonard, Washington, D.C., 3 Pacific tree frogs, caiman lizard.

Maryland Game Department, through David J. Smith, Annapolis, Md., bald eagle.

McKittrick, F. A., Ithaca, N.Y., capybara.

Miller, Robert Fox, Jr., Washington, D.C., 5 South American sucker catfish (*Plecostomus*).

Norfolk, John E., Upper Marlboro, Md., boa constrictor.

Ripley, Dr. S. Dillon, Washington, D.C., 2 rosy-billed pochards.

Rivero, Vincentes Carlos, Caracas, Venezuela, rainbow boa.

Stair, Gary, Washington, D.C., antelope ground squirrel.

Sweeney, Philip Niles, Washington, D.C., striped sand snake.

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Szaba, Mrs. Renée, Glen Burnie, Md., 3 North African pond turtles, 2 red-eared turtles.
Thompson, Lynda, Vienna, Va., 2 golden-mantled ground squirrels.
U.S. Fish and Wildlife Service, Hawaii, nene or Hawaiian goose.
U.S. Naval Medical Research Unit No. 2, Taipei, Taiwan, Far East forest cat.
Ward, Mrs. Bettina B., Middleburg, Va., blue and yellow macaw.

DEPOSITS

During the past year rare or valuable specimens have been dispersed to locations thought to have good breeding conditions as well as better living accommodations than could be provided at the National Zoological Park while new construction is in progress under its capital improvement program. Other animals have been dispersed with the understanding that they or similar specimens will be returned when suitable exhibition areas have been completed here in the park.

These deposits are:

Brookfield Zoo, Brookfield, Ill., female Dall sheep.
Busch Gardens, Tampa, Fla., male concave-casqued hornbill, female Solomon Islands cockatoo.
Dallas Zoo, Dallas, Tex., a female saiga antelope.
Defense General Supply Center Preserve, Richmond, Va., male American elk.
Houston Zoo, Houston, Tex., 2 purple-crested touracos.
National Geographic Society, Washington, D.C., macaw.
Patuxent Wildlife Refuge, Laurel, Md., barred owl.
St. Louis Zoo, St. Louis, Mo., male gaur, 3 king penguins, Adélie penguin, female chimpanzee.

EXCHANGES

The National Zoological Park participates in a continuing program of exchanging surplus animals with zoos of other countries. Notable exchange arrangements were made with several foreign organizations. Ueno Zoological Gardens, Tokyo, Japan, received a pair of Townsend's chipmunks and a pair of golden-manteled ground squirrels. Dudley Zoo, Worcestershire, England, received an assortment of 19 snakes. The zoo in West Berlin received a pair of canvasback ducks, a pair of wood ducks, and a female whistling swan. The Hanover Zoo in Germany received a female black leopard cub. A pair of jaguars and a pair of Canadian lynxes were shipped to the Alipore Zoo in Calcutta, India, and other surplus animals will be shipped later as part of an exchange agreement under which the associate director acquired several hundred birds from India, including such interesting specimens as koels, racket-tailed drongos, several hornbills, painted and black-necked storks, over a hundred assorted parakeets, and many other colorful small birds.

Animals obtained through exchange were:

Baltimore Zoo, Baltimore, Md., 2 whistling swans.
Bronx Zoo, New York, N.Y., springhaas.

Brookfield Zoo, Brookfield, Ill., Arabian camel.

Calgary Zoological Society, Alberta, Canada, 2 hoary marmots, 5 Canadian lynxes.

Cincinnati Zoo, Cincinnati, Ohio, jaguar.

Franklin Park Zoo, Boston, Mass., giant salamander, 2 rhinoceros iguanas.

Gillmore, Harry, Monrovia, Liberia, 3 African pythons.

Handleman, Stanley, New York, N.Y., 2 Negev spiny mice.

Highland Park Zoo, Pittsburgh, Pa., spotted leopard.

Houston Zoo, Houston, Tex., 10 southern copperheads, 2 blotched water snakes, yellow-bellied water snake, 3 broad-banded water snakes, nine-banded armadillo.

Louisville Zoo, Louisville, Ky., olingo.

Portland Zoological Gardens, Portland, Oreg., Kodiak bear cub.

Rand, Peter, Washington, D.C., slow loris.

Roundlake Waterfowl Station, Roundlake, Minn., 8 giant Canada geese.

Ruhe, Heinz, Thousand Oaks, Calif., 2 Celebes apes, 2 Moor macaques.

San Diego Zoo, San Diego, Calif., 6 salvator lizards.

Southwick Game Farm, Blackstone, Mass., jaguar.

Tote-Em-In-Zoo, Wilmington, N.C., 2 curly-crested toucans, 4 titi monkeys, 3 macaws, 2 tamanduas, 2 yellow-banded kraits, 2 northern copperheads, 30 water snakes.

Ueno Zoo, Tokyo, Japan, 2 Seibold's chipmunks, 2 Formosan tree squirrels.

Wild Cargo, Hollywood, Fla., 3 day geckos.

Zinner, Hermann, Vienna, Austria, 4 skinks, 6 Agamid lizards, 2 European glass snakes, 6 worm snakes, 3 Contina snakes, 7 European vipers, 3 European smooth snakes, 11 European glass lizards, 1 European grass snake, 2 tesselated water snakes, 4 Aesculapian snakes.

The following animals were sent to other zoos and to private collectors in exchange:

Boehm, Edward M., Trenton, N.J., 2 junglefowl, 2 wood ducks.

British Embassy, Washington, D.C., peacock.

Canal Zone Biological Area, Balboa, Canal Zone, Panama, 5 titi monkeys.

Cincinnati Zoo, Cincinnati, Ohio, ring-tailed lemur, chimpanzee.

Cunningham Wild Animal Park, Augusta, Kans., red deer.

Delmarva Zoological Society, Salisbury, Md., 4 wood ducks.

Detroit Zoo, Royal Oak, Mich., Patagonian cavy.

Franklin Park Zoo, Boston, Mass., Patagonian cavy, 2 lion cubs, European brown bear cub.

Palmer Chemical Company, Douglasville, Ga., black spider monkey, Java macaque.

Rand, Peter, Washington, D.C., boa constrictor.

Roger Williams Park Zoo, Providence, R.I., 2 wood ducks.

Ruhe, Heinz, Thousand Oaks, Calif., 20 wood ducks, 17 canvasback ducks, 12 ringneck ducks, 12 lesser scaups, 5 red-headed ducks.

Southeast Pet Shop, Washington, D.C., 22 chinchillas.

Southwick Game Farm, Blackstone, Mass., black leopard, 5 canvasback ducks, mute swan, 3 black swans, 12 lesser scaups, 5 whistling swans, gibbon.

Tote-Em-in-Zoo, Wilmington, N.C., Canadian lynx, 4 gelada baboons, 2 woodchucks, Central American opossum, spotted leopard, 3 sika deer, red deer, axis deer, 2 Virginia deer, 2 white fallow deer.

Wild Cargo, Hollywood, Fla., 2 northern copperheads, 2 Taiwan cobras.

PURCHASES

While the associate director was in India, he was able to acquire 10 Indian flying foxes. These are the first of their kind to be brought into the United States under the revised regulations of the Department of the Interior through the cooperation of D. H. Janzen, director, Bureau of Sport Fisheries and Wildlife, Fish and Wildlife Service.

Other specimens purchased in India were 2 pairs of rosy pelicans, 6 lion-tailed macaques, a female golden cat, a female leopard cat, 8 spot-billed ducks, 12 pairs of assorted parakeets, 12 comb ducks, and 2 lesser pied hornbills. Arrangements were made for the purchase of other specimens which will be shipped when accommodations have been completed for them here at the zoo.

Other purchases of interest were:

3 Costa Rican rear-fanged snakes
2 hyraxes
1 South American short-eared dog
3 Gila monsters
1 scarlet macaw
2 wood rails
3 chuckwallas
2 beaded lizards
1 caiman
6 Western skinks
2 purple-created touracos
4 Townsend's chipmunks
1 Eastern diamondback rattlesnake
1 red uakari
1 wattled guan
5 pygmy marmosets
2 cantils
1 Malayan box turtle
12 Southwestern fence lizards

STATUS OF THE COLLECTION

Class	Orders	Families	Species or subspecies	Individuals
Mammals	14	51	237	666
Birds	20	65	340	1, 033
Reptiles	4	28	199	739
Amphibians	2	9	25	105
Fishes	4	9	23	120
Arthropods	3	3	4	78
Mollusks	1	1	1	30
Total	48	166	829	2, 771

In the following lists of mammals and birds, sex is given where known; 1.0 indicates one male, 0.1 indicates one female, 1.1 indicates one male and one female. A plus sign (+) indicates young animals of which the sex is not yet known.

ANIMALS IN THE COLLECTION ON JUNE 30, 1964

MAMMALS

MONOTREMATA

Family and common name	*Scientific name*	*Number*
Tachyglossidae:		
Echidna, or spiny anteater.	*Tachyglossus aculeatus*	0.1

MARSUPIALIA

Family and common name	*Scientific name*	*Number*
Didelphidae:		
Opossum	*Didelphis marsupialis virginiana*	1.0
Central American opossum.	*Didelphis marsupialis*	1.0
Phalangeridae:		
Sugar glider	*Petaurus breviceps*	1.1
Squirrel glider	*Petaurus norfolcensis*	1.2
Phascolomidae:		
Hairy-nosed wombat	*Lasiorhinus latifrons*	2.0
Mainland wombat	*Wombatus hirsutus*	0.1
Macropodidae:		
Rat kangaroo	*Potorous* sp	2.3

INSECTIVORA

Family and common name	*Scientific name*	*Number*
Erinaceidae:		
European hedgehog	*Erinaceus europaeus*	2.0
Soricidae:		
Short-tailed shrew	*Blarina brevicauda*	1
Talpidae:		
Eastern mole	*Scalopus aquaticus*	1

CHIROPTERA

Family and common name	*Scientific name*	*Number*
Pteropodidae:		
Flying fox, or giant fruit bat.	*Pteropus giganteus*	10

PRIMATES

Family and common name	*Scientific name*	*Number*
Lemuridae:		
Ring-tailed lemur	*Lemur catta*	1.2
Brown lemur	*Lemur fulvus*	1.0
Lorisidae:		
Tickell's slow loris	*Nycticebus c. tenasserimensis*	0.1
Great galago	*Galago crassicaudatus*	1.1
Bushbaby	*Galago senegalensis zanzibaricus*	2.0
Common potto	*Perodicticus potto*	0.1
Cebidae:		
Douroucouli	*Aotus trivirgatus*	2.0
Red uakari	*Cacajao rubicundis*	0.1
White-faced saki	*Pithecia pithecia*	0.1
Capuchin	*Cebus capucinus*	3.5
Weeping capuchin	*Cebus griseus*	1.0
Squirrel monkey	*Saimiri sciureus*	2.3+1
Spider monkey	*Ateles geoffroyi*	1.5
Black spider monkey	*Ateles fusciceps*	1.3+2
Woolly monkey	*Lagothrix* sp	1.2

Family and common name	Scientific name	Number
Callithricidae:		
Pygmy marmoset	*Cebuella pygmaea*	1.1
Geoffroy's marmoset	*Oedipomidas spixii*	1.1
Cottontop marmoset	*Saguinus oedipus*	1.0
Hybrid marmoset	*Saguinus midas* × *S. oedipus*	1
Moustached marmoset	*Saguinus mystax*	1.1
Cercopithecidae:		
Toque, or bonnet macaque.	*Macaca sinica*	1.1
Philippine macaque	*Macaca philippinensis*	1.0
Crab-eating macaque	*Macaca irus*	0.1
Hybrid macaque	*M. i. mordax* × *M. philippinensis*	1.0
Rhesus monkey	*Macaca mulatta*	3.1
Javan macaque	*Macaca irus mordax*	2.1
Formosan macaque	*Macaca cyclopis*	1.1
Red-faced macaque	*Macaca speciosa*	0.1
Wanderoo, or lion-tailed macaque.	*Macaca silenus*	1.2
Barbary ape	*Macaca sylvanus*	5.8+2
Moor macaque	*Macaca maurus*	1.2
Crested macaque, or Celebes ape.	*Cynopithecus niger*	1.0
Gray-cheeked mangabey.	*Cercocebus albigena*	0.1
Agile mangabey	*Cercocebus agilis*	1.0
Golden-bellied mangabey.	*Cercocebus chrysogaster*	1.0
Red-crowned mangabey.	*Cercocebus torquatus*	1.1
Sooty mangabey	*Cercocebus fuliginosus*	3.2
Crested mangabey	*Cercocebus aterrimus*	1.0
Black-crested mangabey.	*Cercocebus aterrimus*	1.1
Drill	*Mandrillus leucophaeus*	1.0
Olive baboon	*Papio anubis*	3.2
Gelada baboon	*Theropithecus gelada*	3.4
Chacma baboon	*Papio comatus*	1.0
Vervet guenon	*Cercopithecus aethiops*	2.1
Green guenon	*Cercopithecus aethiops*	1.2
Grivet guenon (color variant).	*Cercopithecus aethiops*	0.1
Moustached monkey	*Cercopithecus cephus*	1.2
Diana monkey	*Cercopithecus diana*	1.0
Roloway monkey	*Cercopithecus diana roloway*	0.1
DeBrazza's monkey	*Cercopithecus neglectus*	1.0
White-nosed guenon	*Cercopithecus nictitans*	0.1
Allen's swamp monkey	*Allenopithecus nigroviridis*	1.1
Patas monkey	*Erythrocebus* sp	1.0
Spectacled, or Phayre's, langur.	*Presbytis phayrei*	1.0
Langur	*Presbytis entellus*	0.1
Crested entellus monkey.	*Presbytis c. cristatus*	1.0

Family and common name	Scientific name	Number
Pongidae:		
White-handed gibbon	*Hylobates lar*	1.0
Wau-wau gibbon	*Hylobates moloch*	0.1
Hybrid gibbon	*Hylobates lar*×*Hylobates* sp	0.4
Siamang gibbon	*Symphalangus syndactylus*	1.0
Sumatran orangutan	*Pongo pygmaeus*	1.1
Bornean orangutan	*Pongo pygmaeus*	0.1
Chimpanzee	*Pan satyrus*	3.2
Lowland gorilla	*Gorilla gorilla*	3.1
	EDENTATA	
Myrmecophagidae:		
Giant anteater	*Mymecophaga tridactyla*	0.1
Tamandua, or collared anteater.	*Tamandua tetradactyla*	1.1
Bradypodidae:		
Two-toed sloth	*Choloepus didactylus*	3.3
Dasypodidae:		
Nine-banded armadillo	*Dasypus novemcinctus*	2.2
	RODENTIA	
Sciuridae:		
European red squirrel	*Sciurus vulgaris*	2.2
Gray squirrel, albino	*Sciurus carolinensis*	0.2
Tassel-eared, or Abert's, squirrel.	*Sciurus aberti*	1.0
Western fox squirrel	*Sciurus niger*	1.0
Southern fox squirrel	*Sciurus niger*	0.1
Indian palm squirrel	*Funambulus palmarum*	0.1
Tricolored squirrel	*Callosciurus prevosti*	0.1
Formosan tree squirrel	*Callosciurus erythraeus*	2.2
Woodchuck, or groundhog.	*Marmota monax*	1.2
Hoary marmot	*Marmota caligata*	1.1
Prairie-dog	*Cynomys ludovicianus*	24
California ground squirrel.	*Citellus beecheyi*	1.2
Washington ground squirrel.	*Citellus washingtoni*	1.0
Antelope ground squirrel.	*Citellus* sp	1.0
Golden-mantled ground squirrel.	*Citellus lateralis*	1.3
Round-tailed ground squirrel.	*Citellus tereticaudus*	1.0
Eastern chipmunk	*Tamias striatus*	1.2
Eastern chipmunk, albino.	*Tamias striatus*	1.0
Yellow pine chipmunk	*Eutamias amoenus*	0.1
Siebold's chipmunk	*Eutamias sibericus*	1.1
Eastern flying squirrel	*Glaucomys volans*	1.2
Heteromyidae:		
Kangaroo rat	*Dipodomys* sp	3.0

Family and common name	*Scientific name*	*Number*
Castoridae:		
Beaver	*Castor canadensis*	3
Pedetidae:		
Cape jumping hare	*Pedetes capensis*	2.2
Cricetidae:		
White-footed mouse	*Peromyscus* sp	1.4
East African maned rat.	*Lophiomys ibeanus*	2.0
Fat-tailed gerbil	*Pachyuromys duprasi*	2.2
Muridae:		
Egyptian spiny mouse	*Acomys cahirinus*	11.11
Egyptian spiny mouse	*Acomys dimidiatus*	1.5
Negev spiny mouse	*Acomys* sp	2
Giant forest rat	*Cricetomys gambianus* ssp	1.0
Slender-tailed cloud rat.	*Phloeomys cumingii*	1.0
Gliridae:		
Garden dormouse	*Eliomys quercinus*	0.1
Hystricidae:		
Malay porcupine	*Acanthion brachyura*	1.0
African porcupine	*Hystrix cristata*	2.4
Brush-tailed porcupine.	*Atherurus* sp	1
Palawan porcupine	*Thecurus pumilus*	1.1
Caviidae:		
Patagonian cavy	*Dolichotis patagonum*	3.2
Dasyproctidae:		
Hairy-rumped agouti	*Dasyprocta prymnolopha*	2.0
Agouti, dark phase	*Dasyprocta prymnolopha*	2.1
Acouchy	*Myoprocta acouchy*	1.0
Chinchillidae:		
Mountain viscacha	*Lagidium* sp	0.1
Chinchilla	*Chinchilla chinchilla*	2.2
Hydrochoeridae:		
Capybara	*Hydrochoerus hydrochoerus*	0.1

CARNIVORA

Canidae:		
Dingo	*Canis familiaris dingo*	1.2
Coyote	*Canis latrans*	0.1
Common jackal	*Canis aureus*	1.1
Timber wolf	*Canis lupus nubilus*	1.4
Texas red wolf	*Canis niger rufus*	0.1
Fennec	*Fennecus zerda*	1.1
Gray fox	*Urocyon cinereoargenteus*	1.2
Red fox	*Vulpes fulva*	1.0
Raccoon dog	*Nyctereutes procyonoides*	0.1
Short-eared dog	*Atelocynus microtis*	0.1
Cape hunting dog	*Lycaon pictus*	1.1
Ursidae:		
Spectacled bear	*Tremarctos ornatus*	1.0
Himalayan bear	*Selenarctos thibetanus*	0.1
Japanese black bear	*Selenarctos thibetanus japonicus*	1.0

Family and common name	*Scientific name*	*Number*
Ursidae—Continued		
Korean bear	*Selenarctos thibetanus ussuricus*	1.1
European brown bear	*Ursus arctos*	1.1
Iranian brown bear	*Ursus arctos syriacus*	1.1
Grizzly bear	*Ursus horribilis*	1.1
Kodiak bear	*Ursus middendorffi*	1.0
Black bear	*Euarctos americanus*	1.1
Polar bear	*Thalarctos maritimus*	1.2
Hybrid bear	*Thalarctos maritimus*×*Ursus middendorffi*	2.1
Malayan sun bear	*Helarctos malayanus*	0.2
Sloth bear	*Melursus ursinus*	1.1
Procyonidae:		
Cacomistle	*Bassariscus astutus*	2.2
Raccoon	*Procyon lotor*	1.3
Raccoon, albino	*Procyon lotor*	0.1
Raccoon, black phase	*Procyon lotor*	1.0
Coatimundi	*Nasua nasua*	1.2
Peruvian coatimundi	*Nasua nasua dorsalis*	1.1
Kinkajou	*Potos flavus*	2.2
Olingo	*Bassaricyon gabbi*	1.1
Mustelidae:		
Marten	*Martes americana*	0.1
Fisher	*Martes pennanti*	0.1
Yellow-throated marten.	*Martes flavigula henrici*	0.2
British Guiana tayra	*Eira barbara poliocephala*	1.1
Grison	*Galictis allimandi*	1.0
Zorilla	*Ictonyx striatus*	1.0
Wolverine	*Gulo gulo luscus*	0.1
Ratel	*Mellivora capensis*	1.0
Eurasian badger	*Meles meles*	0.1
American badger	*Taxidea taxus*	1.0
Golden-bellied ferret-badger.	*Melogale moschata subaurantiaca*	1.2
Common skunk	*Mephitis mephitis*	0.1
River otter	*Lutra canadensis*	2.0
Viverridae:		
Genet	*Genetta genetta neumanni*	2.5
Formosan spotted civet	*Viverricula indica*	1.1
Linsang	*Prionodon linsang*	0.1
African palm civet	*Nandinia binotata*	1.1
Formosan masked civet.	*Paguma larvata taivana*	1.0
Binturong	*Arctictis binturong*	1.0
African water civet	*Atilax paludinosus*	1.4+2
African banded mongoose.	*Mungos mungo grisonax*	1.1
Cusimanse	*Crossarchus fasciatus*	0.1
White-tailed mongoose	*Ichneumia albicauda*	1.0
Black-footed mongoose	*Bdeogale* sp	1.1
Hyaenidae:		
Striped hyena	*Hyaena hyaena*	1.1

Family and common name	*Scientific name*	*Number*
Felidae:		
Bobcat	*Lynx rufus*	1.1
Canadian lynx	*Lynx canadensis*	1.2
Jungle cat	*Felis chaus*	1.1
Pallas's cat	*Felis manual*	1.0
Serval	*Felis serval*	0.2
Far East forest cat	*Felis euptilura*	0.1
Leopard cat	*Felis bengalensis*	1.0
Golden cat	*Felis aurata*	1.1
Ocelot	*Felis pardalis*	1.1
Jaguarondi	*Felis yagouaroundi*	1.1
Puma	*Felis concolor*	1.1
Leopard	*Panthera pardus*	3.1
Black leopard	*Panthera pardus*	1.1
Lion	*Panthera leo*	2.2
Bengal tiger	*Panthera tigris*	3.2
White Bengal tiger	*Panthera tigris*	1.1
Jaguar	*Panthera onca*	1.0
Clouded leopard	*Neofelis nebulosa*	2.0
Snow leopard	*Uncia uncia*	1.0
Cheetah	*Acinonyx jubata*	1.1
	PINNIPEDIA	
Otariidae:		
California sea-lion	*Zalophus californianus*	3.3
Patagonian sea-lion	*Otaria flavescens*	0.1
Phocidae:		
Harbor seal	*Phoca vitulina*	1.1
	TUBULIDENTATA	
Orycteropodidae:		
Aardvark	*Orycteropus after*	1.0
	PROBOSCIDEA	
Elephantidae:		
African elephant	*Loxodonta africana*	0.1
Forest elephant	*Loxodonta cyclotis*	1.0
Indian elephant	*Elephas maximus*	0.2
	HYRACOIDEA	
Procaviidae:		
Rock hyrax	*Procavia capensis*	2.2
	PERISSODACTYLA	
Equidae:		
Mongolian wild horse	*Equus przewalskii*	1.0
Grevy's zebra	*Equus grevyi*	1.2
Grant's zebra	*Equus burchelli*	1.5
Burro, or donkey	*Equus asinus*	1.0
Tapiridae:		
Brazilian tapir	*Tapirus terrestris*	1.1
Rhinocerotidae:		
Indian one-horned rhinoceros.	*Rhinoceros unicornis*	1.1

Family and common name	*Scientific name*	*Number*
Rhinocerotidae—Continued		
African black rhinoceros.	*Diceros bicornis*	1.1
White, or square-lipped, rhinoceros.	*Ceratotherium simum*	1.1
ARTIODACTYLA		
Tayassuidae:		
Collared peccary	*Tayassu tajacu*	6.6
Hippopotamidae:		
Hippopotamus	*Hippopotamus amphibius*	2.1
Pygmy hippopotamus	*Choeropsis liberiensis*	3.5
Camelidae:		
Arabian camel	*Camelus dromedarius*	1.0
Bactrian camel	*Camelus bactrianus*	0.1
Llama	*Lama glama*	3.4
Guanaco	*Lama glama guanicoe*	1.0
Alpaca	*Lama pacos*	1.1
Cervidae:		
White fallow deer	*Dama dama*	2.3
Axis deer	*Axis axis*	4.2
Red deer	*Cervus elaphus*	1.5
Sika deer	*Cervus nippon*	1.7
Père David's deer	*Elaphurus davidianus*	1.0
White-tailed, or Virginia, deer.	*Odocoileus virginianus*	0.2
American elk	*Cervus canadensis*	*1.0
Forest caribou	*Rangifer caribou*	0.1
Reindeer	*Rangifer tarandus*	3.9
Hybrid reindeer	*Rangifer tarandus* × *R. caribou*	0.1
Giraffidae:		
Masai giraffe	*Giraffa c. tippelskirchi*	1.2
Bovidae:		
Sitatunga	*Tragelaphus spekii*	1.0
Anoa	*Anoa depressicornis*	1.1
Yak	*Poephagus grunniens*	1.3
Gaur	*Bibos gaurus*	*2.0
Cape buffalo	*Syncerus caffer*	1.4
American bison	*Bison bison*	1.0
Brindled gnu	*Connochaetes taurinus*	1.4
Maxwell's duiker	*Cephalophus maxwellii*	1.0
Dorcas gazelle	*Gazella dorcas*	3.5
Saiga antelope	*Saiga tatarica*	*0.1
Rocky Mountain goat	*Oreamnos americanus*	0.1
Himalayan tahr	*Hemitragus jemlahicus*	0.1
African pygmy goat	*Capra hircus*	4.1
Ibex	*Capra ibex*	1.0
Aoudad, or Barbary sheep.	*Ammotragus lervia*	1.1
Dall sheep	*Ovis dalli*	*0.1
Big-horn sheep	*Ovis canadensis*	1.1

*On deposit at another zoo or sanctuary.

BIRDS

Family and common name	Scientific name	Number
SPHENISCIFORMES		
Spheniscidae:		
King penguin	*Aptenodytes patagonica*	*3
Adélie penguin	*Pygoscelis adeliae*	*1
STRUTHIONIFORMES		
Struthionidae:		
Ostrich	*Struthio camelus*	1.0
RHEIFORMES		
Rheidae:		
Rhea	*Rhea americana*	1.0
CASUARIIFORMES		
Casuariidae:		
Double-wattled cassowary.	*Casuarius bicarunculatus*	1.1
Dromiceidae:		
Emu	*Dromiceius novaehollandiae*	1.1
TINAMIFORMES		
Tinamidae:		
Pileated tinamou	*Crypturellus soui panamensis*	1
PROCELLARIIFORMES		
Diomedeidae:		
Black-footed albatross	*Diomedea nigripes*	1.0
PELECANIFORMES		
Pelecanidae:		
Rose-colored pelican	*Pelecanus onocrotalus*	2.2
White pelican	*Pelecanus erythrorhynchos*	2
Brown pelican	*Pelecanus occidentalis*	1
Dalmatian pelican	*Pelecanus crispus*	2
Phalacrocoracidae:		
Double-crested cormorant.	*Phalacrocorax auritus auritus*	3
European cormorant	*Phalacrocorax carbo*	6
CICONIIFORMES		
Ardeidae:		
American egret	*Dichromanassa rufescens rufescens*	7
Eastern green heron	*Butorides virescens*	2
Louisiana heron	*Hydranassa tricolor*	1
Black-crowned night heron.	*Nycticorax nycticorax*	11
American bittern	*Botaurus lentiginosus*	1
Tiger bittern	*Tigrisoma lineatum*	1
Balaenicipitidae:		
Shoebill	*Balaeniceps rex*	0.1
Ciconiidae:		
American wood ibis	*Mycteria americana*	2
European white stork	*Ciconia ciconia*	2
White-bellied stork	*Sphenorhynchus abdimia*	2
Black-necked stork	*Xenorhynchus asiaticus*	2
Painted stork	*Ibis leucocephalus*	2

*On deposit at another zoo or sanctuary

Family and common name	*Scientific name*	*Number*
Threskiornithidae:		
White ibis	*Guara alba*	1
Scarlet ibis	*Guara ruber*	2
Black-faced ibis	*Theristicus melanopis*	1
Black-headed ibis	*Threskiornis melanocephala*	1
Eastern glossy ibis	*Plegadis falcinellus falcinellus*	1
Phoenicopteridae:		
Chilean flamingo	*Phoenicopterus chilensis*	1
Cuban flamingo	*Phoenicopterus ruber*	1
Old World flamingo	*Phoenicopterus antiquorum*	1
	ANSERIFORMES	
Anhimidae:		
Crested screamer	*Chauna torquata*	5
Anatidae:		
Coscoroba swan	*Coscoroba coscoroba*	2.2
Mute swan	*Cygnus olor*	1.1
Black-necked swan	*Cygnus melanocoriphus*	2
Whooper swan	*Olor cygnus*	1.2
Trumpeter swan	*Olor buccinator*	1.1
Black swan	*Chenopis atrata*	2.2+2
Egyptian goose	*Alopochen aegyptiacus*	4
White-fronted goose	*Anser albifrons*	3
Indian bar-headed goose.	*Anser indicus*	3.2
Emperor goose	*Anser canagicus*	2
Blue goose	*Anser caerulescens*	5
Lesser snow goose	*Anser caerulescens caerulescens*	2
Greater snow goose	*Anser caerulescens atlanticus*	5
Ross's goose	*Anser rossii*	4
Nene, or Hawaiian goose.	*Branta sandvicensis*	2.0
Red-breasted goose	*Branta ruficollis*	2.2
Canada goose	*Branta canadensis*	22
Canada goose × Lesser snow goose, hybrid.	*Branta canadensis* × *Anser caerulescens*	1
Lesser Canada goose	*Branta canadensis*	4
Giant Canada goose	*Branta canadensis maxima*	4.6
Cackling goose	*Branta canadensis*	1.1
White-cheeked goose	*Branta canadensis*	2
Fulvous tree duck	*Dendrocygna bicolor*	0.1
Wood duck	*Aix sponsa*	90
Mandarin duck	*Aix galericulata*	3.2
Pintail duck	*Anas acuta*	1.1
Green-winged teal	*Anas crecca*	1.0
Gadwall	*Anas strepera*	3.1
European widgeon	*Anas penelope*	2.0
Spot-billed duck	*Anas poecilorhyncha*	3.2
Mallard duck	*Anas platyrhynchos*	60
Black duck	*Anas rubripes*	6.2
Greater scaup duck	*Aythya marila*	5.0
Lesser scaup duck	*Aythya affinis*	6.3

Family and common name	*Scientific name*	*Number*
Anatidae—Continued		
Redhead	*Aythya americana*	1.0
Ring-necked duck	*Aythya collaris*	7.0
Canvasback duck	*Aythya valisineria*	1.0
Indian cotton teal	*Nettapus coromandelianus*	0.1
Rosy-billed pochard	*Metopiana peposaca*	2.1
American goldeneye	*Bucephala clangula*	0.1
Baldpate	*Mareca americana*	5.0
Hooded merganser	*Lophodytes cucullatus*	1.0
Comb duck	*Sarkidiornis melanotos*	4.2
Ruddy shelduck	*Casarca ferruginea*	3.3
FALCONIFORMES		
Cathartidae:		
Andean condor	*Vultur gryphus*	1.0
King vulture	*Sarcoramphus papa*	1
Sagittariidae:		
Secretarybird	*Sagittarius serpentarius*	1.1
Accipitridae:		
Hooded vulture	*Necrosyrtes monachus*	1
Griffon vulture	*Gyps fulvus*	1
Rüppell's vulture	*Gyps ruppellii*	1
Red-winged hawk	*Heterospizias meridionalis*	1
Red-tailed hawk	*Buteo jamaicensis*	2
Swainson's hawk	*Buteo swainsoni*	1
Red-shouldered hawk	*Buteo lineatus*	1
Manduyt's hawk eagle	*Spizaetus ornatus*	1
Black-crested eagle	*Lophaetus occipitalis*	1
Golden eagle	*Aquila chrysaetos*	5
Imperial eagle	*Aquila heliaca*	2
White-breasted sea eagle.	*Haliaeetus leucogaster*	1
Pallas's eagle	*Haliaeetus leucoryphus*	1
Bald eagle	*Haliaeetus leucocephalus*	8
Bateleur eagle	*Terathopius ecaudatus*	1
Lammergeier	*Gypaetus barbatus*	1
Falconidae:		
Sparrow hawk	*Falco sparverius*	2
Duck hawk	*Falco peregrinus anatum*	1
Red-footed falcon	*Falco vespertinus*	1
Feilden's falconet	*Neohierax cinereiceps*	1
Forest falcon	*Micrastur semitorquatus*	2
Audubon's caracara	*Polyborus cheriway*	2
White-throated caracara.	*Phalcoboenus albogularis*	1
GALLIFORMES		
Megapodiidae:		
Brush turkey	*Alectura lathami*	1.0
Cracidae:		
Wattled curassow	*Crax globulosa*	1.1
White-headed piping guan.	*Pipile cumanemsis*	1.0
Wattled guan	*Pipile* sp	0.1

Family and common name	*Scientific name*	*Number*
Cracidae—Continued		
Gambel's quail	*Lophortyx gambeli*	1.0
Valley quail	*Lophortyx californica vallicola*	2
Rain quail	*Turnix* sp	11
Argus pheasant	*Argusianus argus*	1.0
Golden pheasant	*Chrysolophus pictus*	0.2
Black-backed kaleege pheasant.	*Gennaeus melanonotus*	1.1
Silver pheasant	*Gennaeus nycthemerus*	1.0
Ring-necked pheasant	*Phasianus colchicus*	1.2
Ring-necked pheasant, albino.	*Phasianus colchicus*	0.1
Ring-necked pheasant × Green pheasant, hybrid.	*Phasianus colchicus* × *Phasianus versicolor*	1.0
Bhutan, or gray peacock-pheasant.	*Polyplectron bicalcaratum*	2.1
Palawan pheasant	*Polyplectron chinquis*	1.1
Peafowl	*Pavo cristatus*	3.3
Red junglefowl	*Gallus gallus*	1.0
Chukar partridge	*Alectoris graeca*	1
Painted partridge	*Francolinus pictus*	1
Gray partridge	*Francolinus pondicerianus*	1.1
Black partridge	*Melanoperdix nigra*	3.4
Numididae:		
Vulturine guineafowl	*Acryllium vulturinum*	1
	GRUIFORMES	
Gruidae:		
Siberian crane	*Grus leucogeranus*	1.0
European crane	*Grus grus*	2
Sarus crane	*Grus antigone*	1
Demoiselle crane	*Anthropoides virgo*	4
African crowned crane	*Balearica pavonina*	5
Rallidae:		
Cayenne wood rail	*Aramides cajanea*	1
Purple gallinule	*Porphyrula martinica*	1
Indian moorhen	*Gallinula chloropus*	9
Eurypygidae:		
Sun bittern	*Eurypyga helias*	1
Cariamidae:		
Cariama, or seriama	*Cariama cristata*	1
Otididae:		
Kori bustard	*Eupodotis kori*	2.0
Senegal bustard	*Eupodotis senegalensis*	1.0
	CHARADRIIFORMES	
Jacanidae:		
Common jaçana	*Jacana spinosa*	2
Pheasant-tailed jaçana	*Hydrophasianus chirurgus*	2
Charadriidae:		
Australian banded plover.	*Zonifer tricolor*	2
Gray plover	*Pluvialis squatarola*	1

Family and common name	*Scientific name*	*Number*
Charadriidae—Continued		
European lapwing	*Vanellus vanellus*	3
South American lapwing.	*Belonopterus cayennensis*	3
Crocodile bird	*Pluvianus aegyptius*	7
Recurvirostridae:		
Black-necked stilt	*Himantopus mexicanus*	1
Laridae:		
Ring-billed gull	*Larus delawarensis*	3
Laughing gull	*Larus atricilla*	3
Herring gull	*Larus argentatus*	1
Great black-backed gull.	*Larus marinus*	1
Silver gull	*Larus novaehollandiae*	5
COLUMBIFORMES		
Columbidae:		
High-flying Budapest pigeon.	*Columba livia*	1
Black-billed pigeon	*Columba nigrirostris*	1
Triangular spotted pigeon.	*Columba guinea*	2
Imperial green pigeon	*Ducula aenea*	2
Orange-breasted green pigeon.	*Treron bicincta*	2
Crowned pigeon	*Goura victoria*	1
Blue ground dove	*Claravis pretiosa*	2
Ruddy ground dove	*Chaemepelia rufipennis*	1
Indian emerald-winged tree dove.	*Chalcophaps indica*	3
Diamond dove	*Geopelia cuneata*	1
Plain-breasted ground dove.	*Columbigallina minuta*	2
Ground dove	*Columbigallina passerina*	1
Ring-necked dove	*Streptopelia decaocto*	3
Blue-headed ring dove	*Streptopelia tranquebarica*	2
White-winged dove	*Zanaida asiatica*	1
Mourning dove	*Zenaidura macroura*	2
PSITTACIFORMES		
Psittacidae:		
Kea parrot	*Nestor notabilis*	1
Banksian cockatoo	*Calyptorhynchus magnificus*	1.0
White cockatoo	*Kakatoe alba*	1
Solomon Islands cockatoo.	*Kakatoe ducrops*	*1
Sulphur-crested cockatoo.	*Kakatoe galerita*	2
Bare-eyed cockatoo	*Kakatoe sanguinea*	1
Great red-crested cockatoo.	*Katatoe moluccensis*	1
Leadbeater's cockatoo	*Kakatoe leadbeateri*	5
Cockatiel	*Nymphicus hollandicus*	1

*On deposit at another zoo or sanctuary.

Family and common name	*Scientific name*	*Number*
Psittacidae—Continued		
Yellow-and-blue macaw.	*Ara ararauna*	8
Red-and-blue macaw	*Ara chloroptera*	5
Red-blue-and-yellow macaw.	*Ara macao*	5
Illiger's macaw	*Ara maracana*	2
Brown-throated conure.	*Conurus aeruginosus*	5
Petz's parakeet	*Aratinga canicularis*	1
Rusty-cheeked parrot	*Aratinga pertinax*	1
Tovi parakeet	*Brotogeris jugularis*	1
Yellow-naped parrot	*Amazona auropalliata*	2
Blue-fronted parrot	*Amazona aestiva*	1
Double yellow-headed parrot.	*Amazona oratrix*	2
Black-headed, or Nanday, parrot.	*Nandayus nanday*	10
Lineolated parakeet	*Bolborhynchus lineolatus*	4
White-winged parakeet.	*Brotogeris versicolorus*	1
African gray parrot	*Psittacus crithacus*	1
Red-sided eclectus	*Eclectus pectoralis*	2. 1
Greater ring-necked parakeet.	*Psittacula eupatria*	5
Rose-breasted parakeet.	*Psittacula alexandri*	1
Moustached parakeet	*Psittacula fasciata*	1
Lesser ring-necked parakeet.	*Psittacula krameri*	23
Blossom-headed parakeet.	*Psittacula cynocephala*	20
Malabar parakeet	*Psittacula columboides*	5
Quaker parakeet	*Myiopsitta monacha*	6
Grass parakeet	*Melopsittacus undulatus*	1
Red-faced lovebird	*Agapornis pullaria* ssp	2
Rosy-faced lovebird	*Agapornis roseicollis*	1
Masked lovebird	*Agapornis personata*	2
Black-headed caique, or seven-color parrot.	*Pionites melanocephala*	2
Yellow-thighed caique	*Pionites leucogaster*	1
CUCULIFORMES		
Musophagidae:		
White-bellied go-away bird.	*Crinifer leucogaster*	1
White-cheeked turaco	*Tauraco leucotis leucotis*	3
Purple-crested turaco	*Gallirex porphyreolophus*	2
Cuculidae:		
Koel	*Eudynamys scolopacea*	2
Roadrunner	*Geococcyx californianus*	2
Red-winged crested cuckoo.	*Clamator coromandus*	1

STRIGIFORMES

Family and common name	*Scientific name*	*Number*
Tytonidae:		
Barn owl	*Tyto alba*	1
Strigidae:		
Screech owl	*Otus asio*	2
Spectacled owl	*Pulsatrix perspicillata*	2
Malay fishing owl	*Ketupa ketupu*	1
Snowy owl	*Nyctea nyctea*	4
Barred owl	*Strix varia*	5
Nepal brown wood owl	*Strix leptogrammica newarensis*	1
CORACIIFORMES		
Alcedinidae:		
Kookaburra	*Dacelo gigas*	12
White-breasted kingfisher.	*Halcyon smyrnensis*	2
Coraciidae:		
Lilac-breasted roller	*Coracias caudata*	2
Indian roller	*Coracias benghalensis*	2
Bucerotidae:		
Concave-casqued hornbill.	*Buceros bicornis*	2
Pied hornbill	*Anthracoceros malabaricus*	4
Lesser pied hornbill	*Anthracoceros coronatus*	2
Abyssinian ground hornbill.	*Bucorvus abyssinicus*	2
Leadbeater's ground hornbill.	*Bucorvus leadbeateri*	1.0
Wreathed hornbill	*Rhyticeros undulatus*	1
Gray hornbill	*Tockus birostris*	0.1
Crowned hornbill	*Tockus alboterminatus*	1
Yellow-billed hornbill	*Tockus flavirostris*	0.1
Great black-casqued hornbill.	*Ceratogymna atrata*	0.1
PICIFORMES		
Capitonidae:		
Asiatic great barbet	*Megalaima virens*	1
Blue-throated barbet	*Megalaima asiatica*	4
Streaked barbet	*Megalaima lineata*	7
Ramphastidae:		
Keel-billed toucan	*Ramphastos culminatus*	2
Sulphur-and-white-breasted toucan.	*Ramphastos vitellinus*	1
Curly-crested toucanet	*Pteroglossus beauharnaesii*	3
Razor-billed toucanet	*Pteroglossus castanotis*	2
Picidae:		
Flicker	*Colaptes auratus*	1
PASSERIFORMES		
Tyrannidae:		
Kiskadee flycatcher	*Pitangus sulphuratus*	3
Eastern kingbird	*Tyrannus tyrannus*	1
Alaudidae:		
Horned lark	*Eremophila alpestris*	1

Family and common name	*Scientific name*	*Number*
Dicruridae:		
Racket-tailed drongo	*Dicrurus paradiseus*	9
Corvidae:		
Magpie	*Pica pica*	1
Yellow-billed magpie	*Pica nuttalli*	1
Asiatic tree pie	*Crypsirina formosae*	1
Magpie jay	*Calocitta formosa*	1
European jay	*Garrulus glandarius*	1.1
African white-necked crow.	*Corvus albus*	2
American crow	*Corvus brachyrhynchos*	1
Raven	*Corvus corax principalis*	2
Formosan red-billed pie.	*Cissa caerulea*	9
Occipital blue pie	*Cissa occipitalis*	3
Hunting crow	*Cissa chinensis*	7
Paridae:		
Great tit	*Parus major*	1
Sittidae:		
Chestnut-bellied nuthatch.	*Sitta castanea*	1
Timaliidae:		
Scimitar babbler	*Pomatorhinus schisticeps*	1
White-crested laughing thrush.	*Garrulax bicolor*	4
Black-headed sibia	*Heterophasia capistrata*	2
Silver-eared mesia	*Mesia argentauris*	5
Pekin robin	*Leiothrix luteus*	9
Pycnonotidae:		
Black-headed bulbul	*Pycnonotus atriceps*	2
Red-vented bulbul	*Pycnonotus cafer*	4
White-cheeked bulbul	*Pycnonotus leucogenys*	3
White-eared bulbul	*Pycnonotus leucotis*	1
Red-whiskered bulbul	*Pycnonotus jocosus*	7
White-throated bulbul	*Criniger flaveolus*	4
Chloropseidae:		
Gold-fronted chloropsis.	*Chloropsis aurifrons*	9
Blue-winged fruitsucker.	*Chloropsis hardwickii*	1
Blue-mantled fairy bluebird.	*Irena puella malayensis*	1.1
Turdidae:		
Robin, albino	*Turdus migratorius*	1
European song thrush	*Turdus ericetorum*	2
Blackbird	*Turdus merula*	1
Cliff chat	*Thamnolaea cinnamomeiventris*	1
Orange-headed ground thrush.	*Geocichla citrina*	5
Shama thrush	*Copsychus malabaricus*	3
Muscicapidae:		
Verditer flycatcher	*Muscicapa thalassina*	2

Family and common name	*Scientific name*	*Number*
Bombycillidae:		
Cedar waxwing	*Bombycilla cedrorum*	1
Sturnidae:		
Rose-colored pastor	*Pastor roseus*	1
Purple starling	*Lamprocolius purpureus*	3
Burchell's long-tailed starling.	*Lamprotornis caudatus*	1
Amethyst starling	*Cinnyricinclus leucogaster*	1
Tri-colored starling	*Spreo superbus*	1
Jungle mynah	*Acridotheres tristis*	1
Lesser hill mynah	*Gracula religiosa indica*	3
Greater Indian hill mynah.	*Gracula religiosa intermedia*	2
Rothschild's mynah	*Leucopsar rothschildi*	2
Bali mynah	*Sturnus contra jalla*	3
Nectariniidae:		
Variable sunbird	*Cinnyris venustus raccis*	1
Scarlet-tufted malachite sunbird.	*Nectarinia johnstoni*	1
Purple sunbird	*Nectarinia asiatica*	1
Zosteropidae:		
White-eye	*Zosterops palpebrosa*	2
Coerebidae:		
Black-headed sugarbird.	*Chlorophanes spiza*	2
Bananaquit	*Coereba flaveola*	1
Parulidae:		
Kentucky warbler	*Oporornis formosus*	1
Redstart	*Setophaga ruticilla*	1
Ovenbird	*Seiurus aurocapillus*	1
Ploceidae:		
Red-naped widowbird	*Coliuspasser laticauda*	4
Giant whydah	*Diatropura procne*	1
Baya weaver	*Ploceus baya*	3
Vitelline masked weaver.	*Ploceus vitellinus*	1
Red bishop weaver	*Euplectes orix*	1
White-headed nun	*Lonchura maja*	2
Indian silverbill	*Lonchura malabarica*	1
Bengalese finch	*Lonchura* sp	2
Black-headed munia	*Lonchura malacca*	3
Spotted munia	*Lonchura punctulata*	5
Red munia	*Estrilda amandava*	2
Cut-throat weaver finch.	*Amadina fasciata*	1
Lavender finch	*Estrilda coerulescens*	1
Common waxbill	*Estrilda troglodytes*	1
Zebra finch	*Poephila castanotis*	5
Gouldian finch	*Poephila gouldiae*	1
Icteridae:		
Yellow-headed blackbird.	*Xanthocephalus xanthocephalus*	1
Rice grackle	*Psomocolax oryzivora*	2

Family and common name	*Scientific name*	*Number*
Icteridae—Continued		
Swainson's grackle	*Holoquiscalus lugubris*	1
Glossy cowbird	*Molothrus bonariensis*	2
Brown-headed cowbird.	*Molothrus ater*	1
Bay cowbird	*Molothrus badius*	1
Colombian red-eyed cowbird.	*Tangavius armenti*	1
Red-winged blackbird	*Agelaius phoeniceus*	2
Red-breasted marsh-bird.	*Leistes militaris*	4
Thraupidae:		
Blue tanager	*Thraupis cana*	1
White-edged tanager	*Thraupis leucoptera*	1
Yellow-rumped tanager	*Ramphocelus icteronotus*	1
Passerini's tanager	*Ramphocelus passerinii*	1
Maroon, or silver-beaked, tanager.	*Ramphocelus jacapa*	1
Fringillidae:		
Tropical seed finch	*Oryzoborus torridus*	2
Black-throated cardinal.	*Paroaria gularis*	2
European goldfinch	*Carduelis carduelis*	1
Green finch	*Chloris chloris*	1
Lesser yellow finch	*Sicalis luteola*	1
Saffron finch	*Sicalis flaveola*	3
White-lined finch	*Spermophila lineola*	3
Slate-colored junco	*Junco hyemalis*	1
Buff-throated saltator	*Saltator maximus*	1
Tawny-bellied seed-eater.	*Sporophila minuta*	5
Song sparrow	*Melospiza melodia*	1
Dickcissel	*Spiza americana*	3
White-crowned sparrow.	*Zonotrichia leucophrys*	2
Yellowhammer	*Emberiza citrinella*	1
European bunting	*Emberiza calandra*	1
Jacarini finch	*Volatinia jacarini*	2

REPTILES

LORICATA

Alligatoridae:		
Caiman	*Caiman sclerops*	16
Black caiman	*Melanosuchus niger*	3
American alligator	*Alligator mississipiensis*	14
Chinese alligator	*Alligator sinensis*	2
Crocodilidae:		
Broad-nosed crocodile	*Osteolaemus tetraspis*	2
African crocodile	*Crocodylus niloticus*	3
Narrow-nosed crocodile.	*Crocodylus cataphractus*	1
Salt-water crocodile	*Crocodylus porosus*	1
American crocodile	*Crocodylus acutus*	1

Family and common name	*Scientific name*	*Number*
Gavialidae:		
Indian gavial	*Gavialis gangeticus*	1
	CHELONIA	
Chelydridae:		
Snapping turtle	*Chelydra serpentina*	15
Alligator snapping turtle.	*Macrochelys temminckii*	1
Kinosternidae:		
Stinkpot	*Sternotherus odoratus*	4
Mud turtle	*Kinosternon subrubrum*	5
Tropical American mud turtle.	*Kinosternon spurrelli*	3
South American mud turtle.	*Kinosternon cruentatum*	1
Emydidae:		
Tropical American pointed-nosed turtle.	*Geoemyda puncturia*	2
Box turtle	*Terrapene carolina*	63
Gulf Coast box turtle	*Terrapene carolina major*	1
Three-toed box turtle	*Terrapene carolina triunguis*	2
Florida box turtle	*Terrapene carolina bauri*	5
Ornate box turtle	*Terrapene ornata ornata*	1
Kura kura box turtle	*Cuora amboinensis*	3
Diamondback terrapin	*Malaclemys terrapin*	7
Map turtle	*Graptemys geographica*	1
Barbour's map turtle	*Graptemys barbouri*	4
Mississippi map turtle	*Graptemys pseudogeographica kohni*	3
Painted turtle	*Chrysemys picta*	10
Western painted turtle	*Chrysemys picta belli*	9
Southern painted turtle.	*Chrysemys picta dorsalis*	1
Cumberland turtle	*Pseudemys scripta troostii*	7
South American red-lined turtle.	*Pseudemys scripta callirostris*	2
Yellow-bellied turtle	*Pseudemys scripta scripta*	18
Red-eared turtle	*Pseudemys scripta elegans*	36
Red-bellied turtle	*Pseudemys rubriventrirs*	8
Cooter	*Pseudemys floridana*	7
Florida red-bellied turtle.	*Pseudemys nelsoni*	2
Central American turtle.	*Pseudemys ornata*	2
Cuban water turtle	*Pseudemys decussata*	1
Chicken turtle	*Deirochelys reticularia*	3
Spotted turtle	*Clemmys guttata*	2
Wood turtle	*Clemmys insculpta*	5
Iberian pond turtle	*Clemmys leprosa*	5
European water terrapin.	*Clemmys caspica rivulata*	13
European pond turtle	*Emys orbicularis*	2
Blanding's turtle	*Emys blandingii*	5
Reeves's turtle	*Chinemys reevesii*	4

Family and common name	Scientific name	Number
Testudinidae:		
Duncan Island tortoise	*Testudo ephippium*	2
Galapagos tortoise	*Testudo elephantopus vicina*	2
Galapagos tortoise	*Testudo elephantopus*	2
Giant Aldabra tortoise	*Testudo gigantea*	2
South American tortoise.	*Testudo denticulata*	5
Star tortoise	*Testudo elegans*	2
Mountain tortoise	*Testudo emys*	2
Gopher tortoise	*Gopherus polyphemus*	2
Texas tortoise	*Gopherus berlandieri*	1
Pelomedusidae:		
African water turtle	*Pelomedusa sinuata*	2
African black mud turtle.	*Pelusios subniger*	1
Red-faced turtle	*Podocnemis catanatius*	1
Amazon spotted turtle	*Podocnemis unifilis*	5
Chelydidae:		
South American side-necked turtle.	*Batrachemys nasuta*	2
Australian side-necked turtle.	*Chelodina longicollis*	3
Matamata turtle	*Chelys fimbriata*	1
Small side-necked turtle.	*Hydromedusa tectifera*	2
Large side-necked turtle.	*Phrynops hilarii*	7
Krefft's turtle	*Emydura krefftii*	3
Murray turtle	*Emydura macquarrii*	3
South American gibba turtle.	*Mesoclemmys gibba*	2
Flat-headed turtle	*Platemys platycephala*	2
Trionychidae:		
Spiny softshell	*Trionyx ferox*	5
Texas softshell	*Trionyx ferox emoryi*	1
African softshell	*Trionyx triunguis*	2

SAURIA

Family and common name	Scientific name	Number
Gekkonidae:		
Tokay gecko	*Gekko gecko*	27
Day gecko	*Phelsuma cepedianum*	3
Day gecko	*Phelsuma* sp	1
Agamidae:		
Agamid lizard	*Agamid stellio*	4
Agamid lizard	*Agamid* sp	1
Blood-sucker lizard	*Calotes versicolor*	5
Iguanidae:		
Common iguana	*Iguana iguana*	7
Swan Island iguana	*Iguana delicatissima*	1
Basilisk lizard	*Basiliscus* sp	1
Rhinoceros iguana	*Cyclura cornuta*	2
Carolina anole	*Anolis carolinensis*	50
Fence lizard	*Sceloporus undulatus*	11

Family and common name	*Scientific name*	*Number*
Iguanidae—Continued		
Fence lizard	*Sceloporus* sp	3
Plica lizard	*Plica plica*	1
Chuckwalla	*Sauromalus obesus*	4
Scincidae:		
Mourning skink	*Egernia luctuosa*	2
White's skink	*Egernia whitei*	2
Skink	*Eumeces anthracinus*	1
Skink	*Eumeces* sp	1
Five-lined skink	*Eumeces fasciatus*	1
Four-lined skink	*Eumeces tetragrammus*	10
Great Plains skink	*Eumeces obsoletus*	2
Stump-tailed skink	*Tiliqua rugosa*	1
Malayan skink	*Mabuya multifasciata*	2
Gerrhosauridae:		
African plated lizard	*Zonosaurus* sp	1
Madagascar plated lizard.	*Zonosaurus madagascariensis*	1
Plated lizard	*Gerrhosaurus major*	1
Lacertidae:		
European lizard	*Lacerta strigata trilineata*	1
Teiidae:		
Ameiva lizard	*Ameiva ameiva praesignis*	1
Caiman lizard	*Dracaena guianensis*	1
Cordylidae:		
South African spiny lizard.	*Cordylus vandami perkoensis*	2
African spiny lizard	*Cordylus polyzonus*	2
Varanidae:		
Komodo dragon	*Varanus komodoensis*	1
Indian monitor	*Varanus flavescens*	1
Duméril's monitor	*Varanus dumerili*	1
Philippine monitor	*Varanus nuchalis*	1
Malayan monitor	*Varanus salvator*	7
Helodermatidae:		
Gila monster	*Heloderma suspectum*	4
Mexican beaded lizard	*Heloderma horridum*	3
Beaded lizard, black phase.	*Heloderma horridum alvernensis*	1
Anguidae:		
Eastern glass lizard	*Ophisaurus ventralis*	1
European glass lizard	*Ophisaurus apodus*	4
European glass lizard, or slow worm.	*Anguis fragilis*	8
San Diego alligator lizard.	*Gerrhonotus multicarinatus webbi*	1
SERPENTES		
Boidae:		
Cook's tree boa	*Boa cooki*	3
Boa constrictor	*Constrictor constrictor*	4
Emperor boa	*Constrictor imperator*	1
Cuban ground boa	*Tropidophis melanura*	1
Rainbow boa	*Epicrates cenchria*	2

Family and common name	*Scientific name*	*Number*
Boidae—Continued		
Sand boa	*Eryx conica*	1
Ball python	*Python regius*	1
Indian rock python	*Python molurus*	3
Regal python	*Python reticulatus*	4
African python	*Python sebae*	3
Colubridae:		
Eastern king snake	*Lampropeltis getulus getulus*	2
Speckled king snake	*Lampropeltis getulus holbrooki*	2
Florida king snake	*Lampropeltis getulus floridana*	2
Sonora king snake	*Lampropeltis getulus splendida*	1
Scarlet king snake	*Lampropeltis doliata doliata*	2
Tropical king snake	*Lampropeltis doliata polyzonus*	1
Eastern milk snake	*Lampropeltis doliata triangulum*	1
Coastal Plain milk snake	*Lampropeltis doliata temporalis*	1
Mole snake	*Lampropeltis calligaster rhombomaculata*	2
Eastern garter snake	*Thamnophis sirtalis sirtalis*	2
Garter snake, melanistic phase.	*Thamnophis sirtalis*	1
Eastern hog-nosed snake.	*Heterodon platyrhinos*	1
Common water snake	*Natrix sipedon*	3
Broad-banded water snake.	*Natrix sipedon confluens*	1
Red-bellied water snake.	*Natrix erythrogaster erythrogaster*	1
Blotched water snake	*Natrix erythrogaster transversa*	1
Yellow-bellied water snake.	*Natrix erythrogaster flavigaster*	1
European grass snake	*Natrix natrix natrix*	8
European grass snake	*Natrix natrix bilineata*	1
Diamondback water snake.	*Natrix rhombifera*	4
Brown water snake	*Natrix taxispilota*	2
Tessellated water snake.	*Natrix tessellatus*	3
Eastern indigo snake	*Drymarchon corais couperi*	1
Texas indigo snake	*Drymarchon corais crebennus*	1
Mexican indigo snake	*Drymarchon corais* ssp	1
Black rat snake	*Elaphe obsoleta obsoleta*	5
Black rat snake, albino	*Elaphe obsoleta obsoleta*	1
Yellow rat snake	*Elaphe obsoleta quadrivittata*	1
Texas rat snake	*Elaphe obsoleta lindheimeri*	2
Corn snake	*Elaphe guttata guttata*	4
Great Plains rat snake	*Elaphe guttata emoryi*	1
Asiatic striped rat snake.	*Elaphe taeniura*	6
Japanese rat snake	*Elaphe climacophora*	1
Chinese rat snake	*Elaphe carinata*	2
Aesculapian snake	*Elaphe longissima*	3
Aesculapian snake	*Elaphe longissima subgrisea*	1

Family and common name	*Scientific name*	*Number*
Colubridae—Continued		
Banded red snake	*Dinodon rufozonatum*	4
Rainbow snake	*Abastor erythrogrammus*	1
Northern black racer	*Coluber constrictor constrictor*	1
European racer	*Coluber jugularis caspius*	2
Red racer	*Masticophis flagellum piceus*	1
Western coachwhip	*Masticophis flagellum testaceus*	1
Northern ringneck snake.	*Diadophis punctatus edwardsii*	1
Eastern worm snake	*Carphophis amoenus amoenus*	1
Brown snake	*Storeria dekayi*	1
Green vine snake	*Dryophis prasinus*	1
Bull snake	*Pituophis catenifer sayi*	2
Great Basin gopher snake.	*Pituophis catenifer deserticola*	1
File snake	*Simocephalus capensis*	1
Wolf snake	*Lycodon flavomaculatus*	1
Cat-eyed snake	*Eteirodipsas* sp	1
Green-headed tree snake.	*Leptophis mexicanus*	1
Typhlopidae:		
Blind snake	*Typhlops vermicularis*	3
Blind snake	*Typhlops blamus*	3
Elapidae:		
Indian cobra	*Naja naja*	1
Taiwan cobra	*Naja naja atra*	9
King cobra	*Ophiophagus hannah*	2
Many-banded krait	*Bungarus multicinctus*	3
Banded krait	*Bungarus fasciatus*	2
Acrochordidae:		
Elephant trunk snake	*Acrochordus javanicus*	1
Crotalidae:		
Southern copperhead	*Ancistrodon contortrix contortrix*	12
Northern copperhead	*Ancistrodon contortrix mokeson*	4
Broad-banded copperhead	*Ancistrodon contortrix laticinctus*	1
Cottonmouth	*Ancistrodon piscivorus*	3
Western cottonmouth	*Ancistrodon piscivorus leucostoma*	3
Japanese pit viper	*Ancistrodon halys*	1
Green palm viper	*Trimeresurus gramineus*	1
Mamushi	*Trimeresurus elegans*	1
Habu	*Trimeresurus flavoviridis*	2
Okinawa habu	*Trimeresurus okinavensis*	1
Taiwan habu	*Trimeresurus mucrosquamatus*	1
Eastern diamondback rattlesnake.	*Crotalus adamanteus*	1
Timber rattlesnake	*Crotalus horridus*	1
Western diamondback rattlesnake.	*Crotalus atrox*	6
Viperidae:		
European viper	*Vipera berus bosniensis*	1

AMPHIBIANS

CAUDATA

Family and common name	*Scientific name*	*Number*
Cryptobranchidae:		
Giant salamander	*Megalobatrachus japonicus*	3
Amphiumidae:		
Congo eel	*Amphiuma means*	1
Ambystomatidae:		
Axolotl, white phase	*Ambystoma tigrinum*	2
Axolotl	*Ambystoma tigrinum*	3
Spotted salamander	*Ambystoma maculatum*	1
Salamandridae:		
Japanese red-bellied newt.	*Diemictylus pyrrhogaster*	8
Red-spotted newt	*Diemictylus viridescens viridescens*	14
Broken-striped newt	*Diemictylus viridescens dorsalis*	7

SALIENTIA

Bufonidae:		
American toad	*Bufo terrestris americanus*	1
Fowler's toad	*Bufo woodhousei fowleri*	1
Blomberg's toad	*Bufo blombergi*	1
Giant toad	*Bufo marinus*	9
Cuban toad	*Bufo peltocephalus*	6
Crested Central American toad.	*Bufo typhonius*	2
South American pointed-nosed toad.	*Bufo granulosus*	1
Colorada River toad	*Bufo alvarius*	2
Western toad	*Bufo boreas*	1
Pipidae:		
Surinam toad	*Pipa pipa*	6
African clawed frog	*Xenopus laevis*	3
Hylidae:		
Pacific tree frog	*Hyla regilla*	3
Gray tree frog	*Hyla versicolor*	1
Microhylidae:		
Narrow-mouthed toad	*Microhyla carolinensis*	2
Ranidae:		
American bullfrog	*Rana catesbeiana*	1
Green frog	*Rana clamitans melanota*	1
Leopard frog	*Rana pipiens*	25

FISHES

NEOCERATODONTOIDEI

Protopteridae:		
African lungfish	*Protopterus annectens*	3

OSTARIOPHYSOIDEI

Characidae:		
Piranha	*Serrasalmus niger*	1
Black tetra	*Gymnocorymbus ternetzi*	1
Metynnis, or silver dollar.	*Metynnis maculatus*	1

Family and common name	*Scientific name*	*Number*
Cyprinidae:		
Zebra danio	*Brachydanio rerio*	1
Tiger barb	*Barbus partipentazona*	1
White cloud mountain fish.	*Tanichthys albonubes*	1
Loricariidae:		
South American sucking catfish.	*Hypostomus plecostomus*	3
Black bullhead	*Ictalurus melas*	1
Electrophoridae:		
Electric eel	*Electrophorus electricus*	6
CYPRINODONTOIDEI		
Poeciliidae:		
Flag-tailed guppy	*Lebistes reticulatus*	10
Guppy	*Lebistes reticulatus*	15
Black mollie	*Mollienesia latipinna*	1
Platy, or moonfish	*Xiphophorus maculatus*	5
Green swordtail	*Xiphophorus* sp	20
Red swordtail	*Xiphophorus* sp	40
PERCOMORPHOIDEI		
Anabantidae:		
Kissing gourami	*Helostoma temmincki*	1
Centrarchidae:		
Common bluegill	*Lepomis macrochirus*	1
Cichlidae:		
Peacock cichlid	*Astronotus ocellatus*	1
Jack Dempsey fish	*Cichlasoma biocellatum*	3
Egyptian mouthbreeder.	*Haplochromis multicolor*	1
African mouthbreeder.	*Pelmatochromis guentheri*	1
Angelfish	*Pterophyllum eimekei*	1
Gobiidae:		
Bumblebee fish	*Brachygobius doriae*	1
CRUSTACEANS		
Cenobitidae:		
Land hermit crab	*Coenobita clypeatus*	29
Key West hermit crab	*Coenobita diogenes*	13
ARANEIDA		
Aviculariidae:		
Tarantula	*Eurypelma* sp	1
ORTHOPTERA		
Blattidae:		
Tropical giant cockroach.	*Blaberus giganteus*	35
MOLLUSKS		
PULMONATA		
Planorbidae:		
Pond snail	*Helisoma trivolvis*	30

REPORT OF THE VETERINARIAN

Nikumba, the adult male gorilla, whose paraplegia was mentioned in last year's Report, made an essentially complete recovery in 8 months. A tentative diagnosis was made of a selective spotty viral infection of the spinal cord. Nikumba was treated daily for approximately 3 months. Chloromycetin succinate and Bejectal, a vitamin-B complex, were injected intramuscularly, by the use of the projectile syringe and the Cap-Chur gun. Methylprednisolone was given orally in Coca Cola syrup. The most noteworthy progress was seen approximately 2½ months after the onset of the paralytic attack when Nikumba was able to stand erect and take two or three steps before returning to a sitting position. His progress since that time has been slow and steady; he has regained his original weight and is moving in a normal manner.

One of the most interesting things that occurred during the treatment period was the gorilla's reaction to the use of the Cap-Chur gun equipment. One could enter the room with empty hands and Nikumba would come to the bars with a desire to hold your arm or your hand, and displayed every evidence of affection. As soon as the equipment was produced, however, Nikumba would retreat to a far corner of the cage or climb to the top of the shift cage. He became very nervous and would swing from the horizontal bars in the cage to escape the administration of the medication. Immediately following the injection Nikumba would realize that the treatment had been completed and would then come forward to the bars and display his normal friendliness.

His recovery has been observed with a great deal of interest because he is not only an excellent specimen of the male lowland gorilla but also a proven sire. The first baby, Tomoka, was born on September 9, 1961. Leonard, a second male, was born on January 10, 1964. The last observed mating of the parent gorillas took place on April 24 and 25, 1963, approximately 2 months before the onset of the paraplegia of the breeding male. It has been necessary for both babies to be raised by the wife of a keeper, since Moka had no milk following either birth. The entire staff is anxiously awaiting Moka's return to a regular menstrual cycle to observe Nikumba's ability to mate following his paralysis.

On December 16, 1963, Deepali, an adult Indian rhinoceros and her baby were received by air from India. Eleven days following the arrival symptoms of an intestinal colic were noted in the adult at 1 p.m., and death occurred at 9 o'clock that evening. An immediate autopsy was performed and the cause of death was found to be a peracute hemorrhagic gastroenteritis. Approximately 4 liters of free blood were found in the stomach and the anterior portion of the small

intestine. This problem was further complicated by the presence of a large number of fringed and diphyllobothrium tapeworms and intestinal flukes, as well as numerous strongyloides. Treatment was instituted immediately to relieve the parasitic infestation of the baby rhino, Rajkumari, with excellent results, and her growth has been quite satisfactory.

On March 4, 1964, the director of the National Zoological Park returned from Djakarta, Indonesia, with a pair of Komodo dragons (*Varanus komodoensis*). The male dragon was 8 feet 11 inches long and weighed approximately 200 pounds. The smaller female was 6 feet long and weighed 75 pounds. The first fecal samples harvested following their arrival revealed a heavy infestation of protozoa with ameboid-like nuclei. On May 21 the large dragon became affected with severe gastric cramps which were relieved by the injection of atropine sulfate, but it died the next day. An intensive autopsy was performed, and the cause of death was established as intestinal and extraintestinal amebiasis. Histopathological sections were made from tissues harvested during the autopsy. Outstanding degeneration was noted in the liver, in which no functional tissue could be found; it consisted entirely of a mass of ameboid-like cysts. This has been reported only once in literature and much more extensive studies are being conducted by the veterinary division in cooperation with the Parasitology Department of George Washington University Medical School and the staff of the Armed Forces Institute of Pathology to determine the incidence of such liver cyst occurrence in our available lizards.

With the assistance of Dr. Thomas Sappington, an internal medicine specialist in Washington, a research program is being developed in the incidence and extent of tissue damage caused by amebae in lizards. This will include a study of the blood picture, parasite history, and possible liver damage caused by amebiasis in the monitor lizard.

A 6-day treatment of the female Komodo dragon consisted of retention enemas of 200 cc. of physiological saline, containing 650 mg. of diodoquin, and intramuscular injections of 500 mg. of tetracycline. In the meantime, tests were being conducted on *Varanus salvator* to determine the lizard's tolerance of 0.0325 mg. of intramuscular emetine hydrochloride as an effort to arrest the extraintestinal amebiasis. This test continued for 6 days with no apparent side effects. After establishing the safety of the drug, the Komodo dragon then received the same dosage. The results were a marked reduction in the number of amebae and flagellates in the stool.

Studies are continuing in the hope of finding a more satisfactory parasiticide for use in various species of mammals, birds, and reptiles. Ambutochloride has been used in canines, as well as reptiles; thiaben-

dazole has been used in equines, rhinoceroses, tapirs, and several monkeys; and a research product, called Alcopar, which contains the bephenium ion, shows a great deal of promise in selected species of animals. To generalize, thiabendazole has been the first product we have used in the zebras that has been so thorough that routine worming has become unnecessary; and the use of Alcopar in the large cats has caused a reduction in the egg count of both ascarid and hookworm.

Bird losses on the shipment arriving from India on December 16 were high, owing primarily to travel trauma. Among 69 waterfowl and pheasants quarantined at Clifton, N.J., 8 undiagnosed deaths occurred. Psittacine birds are required to be quarantined for a period of 90 days under the direction of the U.S. Public Health Service, and 101 birds were placed in a closed quarantine area. Quarantine procedure consists of 45 days on tetracycline-treated seeds, and a further 45-day period of observation. Of the quarantined birds, 48 died and were sent to the Communicable Disease Center. Psittacosis virus was isolated in some of the birds.

Every effort is being made to improve the effectivness of the veterinary division in the care of animal health in the Park. X-ray equipment purchased early in the year has been invaluable in the correction of several fractures. Equipment and supplies have been obtained to institute a system of bacteriological culturing in both living animals and autopsy specimens in an effort to establish the cause of death more definitely, and diagnose illnesses and infections in the living animals more rapidly.

The veterinary division has been fortunate in having the cooperation and assistance of various specialists in the fields of clinical investigation and medicine. Among these men were Dr. Henry Feffer, orthopedist; Dr. Hugo Rizzoli, neurosurgeon; Dr. A. G. Karlsen of the Mayo Clinic in Rochester, Minn.; Dr. F. R. Lucas, director of the Livestock Sanitary Laboratory in Centerville, Md.; Dr. Anthony Morris of the National Institutes of Health, Bethesda, Md.; and Dr. Leonard Marcus and staff, of the Armed Forces Institute of Pathology. Dr. Clarence Hartman, Dr. William McCarten, and Miss Bessie Sonnenberg, parasitologists on the staff of George Washington Medical School, connected with the Tropical Disease Program, have given assistance in the diagnosis of and identification of the parasites that we have encountered in the Zoo, and their advice on treatment has been most helpful.

A Brahminy kite (*Haliastur indus*) collected for the National Zoological Park by the National Geographic Society-Smithsonian Institution Expedition to the East Indies, received September 28, 1937, died on April 18, 1964. This bird had been in the collection 26 years 5 months 21 days.

Following are autopsy statistics for the mortality which occurred at the National Zoological Park during the last fiscal year, and a table of comparison with the past 6 years:

TABLE 1.—*Autopsy statistics, 1958–64*

Mortality, fiscal year 1964				Total mortality past 7 years
Cause	Reptiles [1]	Birds	Mammals	
No autopsy for sundry reasons [2]	126	27	17	1958----550
Attrition (within 14 days after arrival)	1	26	20	1959----472
Systemic diseases [3]	39	36	19	1960----532
Infectious diseases [4]	--------	5	1	1961----517
Parasites	9	3	1	1962----584
Injuries, accidents	19	74	41	1963----636
Euthanasia	--------	2	6	------------
Miscellaneous (stillborn, old age, shock)	7	------	18	------------
Undetermined	36	57	29	------------
Total	237	230	152	1964----619

[1] Included with reptile deaths are amphibians, fishes, and insects.
[2] Reasons include preserving of intact specimen for museum and research, progressed decomposition, insufficient remains in case of predators, etc.
[3] Systemic diseases include acute and chronic diseases of lung, liver, kidney and heart, and intestinal ailments other than parasite involvement, as well as CNS disorders.
[4] Infectious diseases include TB, viremia, toxoplasmodis, etc.

RESEARCH

The National Zoological Park is expanding its scope in the field of animal behavioral studies to programs designed to develop a greater knowledge of animal husbandry as it applies to worldwide conservation efforts.

All possible efforts and means must immediately be turned to the task of preserving representative fauna from all parts of the world. International and national organizations of zoos and wildlife conservators do consonantly strive to preserve those species which are threatened in the countries of habitat. To foster and breed such species is a task well within the capabilities of the zoos and conservation societies of the world. It remains only to know enough about these vanishing animals to recreate at least minimum niches which may result in reversal and establishment of breeding units. To this end the National Zoological Park is participating and cooperating in the following projects:

Group relationships and social niches of the Barbary ape, *Macaca sylvanus*; investigators, Dr. R. K. Lahiri, Director Alipore Zoo, Calcutta, India, and Dr. Charles Southwick, Director, School of Biomedicine, Johns Hopkins University.

Social behavior of titi monkeys, *Callicebus*; investigator, Dr. Martin Moynihan, Canal Zone Biological Area, Balboa, Panama.

Ecology and behavior of *Suncus murinus;* investigator, Dr. Kyle Barbehenn. This work is continuing with emphasis on captive behavior at the National Zoological Park.

The arrangement and structure of the genetic complex in wild animals is an active project in which the National Zoological Park is contributing culture bases to Dr. Kurt Benirschke, department of genetics, Dartmouth University. A great deal of information, which should lead to better understanding of breeding programs, is anticipated.

The National Zoological Park will continue to devote, within the organization, as much time and effort as possible to increase the knowledge of the requirements of wild animals both captive and free. To this end, the zoo plans, at the first opportunity, to activate a section of Animal Research and Behavior.

VISITORS

The 16th International Congress of Zoology was held in Washington from August 20 to 26, and many of the delegates visited the National Zoo. On the night of August 20 approximately 2,000 were taken on a night tour and served refreshments. Members of the American Association of Zoological Parks and Aquariums, meeting in Washington from September 23 to 26, visited the Park frequently and on September 24 were taken on a late-afternoon tour of the Zoo. The annual meeting of the Virginia Herpetological Society was held in the reptile house on December 28 and was attended by 62 members. On June 6, 1964, the same society met again in the reptile house and heard an illustrated lecture on the snakes of Taiwan, given by Dr. R. E. Kuntz.

About 2 p.m. each day the cars then parked in the Zoo are counted and listed according to the State or country from which they come. This is, of course, not a census of the cars coming to the Zoo but is valuable in showing the percentage of attendance by States of people in private automobiles. Many District of Columbia, Maryland, and Virginia cars come to the Zoo to bring guests from other States. The tabulation for fiscal year 1964 is as follows:

	Percentage
Maryland	33.5
Virginia	24.4
District of Columbia	18.8
Pennsylvania	4.3
New York	2.3
North Carolina	1.8
New Jersey	1.4
Ohio	1.3
West Virginia	1.2
Florida	1.0
Massachusetts	.9
Tennessee	.6
Connecticut	.6
South Carolina	.6
California	.6
Illinois	.5
Michigan	.5
Texas	.5
Georgia	.4
Delaware	.4
Indiana	.4
Total	96.0

The remaining 4 percent came from other States, Belgium, Canada, Canal Zone, England, France, Germany, Honduras, Japan, Mexico, Puerto Rico, Thailand, and Turkey. On the days of even small attendance there are cars parked in the Zoo from at least 15 States, Territories, the District of Columbia, and foreign countries.

Owing to the construction work in progress in the Zoo in connection with the redevelopment program, the number of available parking spaces fluctuates between 650 and 1,100.

TABLE 2.—*Number of bus groups visiting the Zoo in fiscal year 1964*

Locality	Number of groups	Number in groups	Locality	Number of groups	Number in groups
Alabama	17	616	Mississippi	2	46
Arkansas	1	33	Missouri	1	32
California	2	49	New Hampshire	3	107
Connecticut	11	339	New Jersey	29	1, 288
District of Columbia	286	9, 978	New York	203	7, 532
Delaware	12	422	North Carolina	203	6, 484
Florida	32	1, 139	Ohio	29	1, 025
Georgia	15	554	Pennsylvania	392	14, 079
Illinois	17	578	Rhode Island	12	389
Indiana	10	330	South Carolina	55	2, 022
Iowa	2	50	Tennessee	53	1, 808
Kansas	1	18	Texas	9	203
Kentucky	13	433	Virginia	894	35, 227
Massachusetts	20	727	Vermont	1	39
Maryland	1, 161	44, 028	Washington	1	29
Maine	2	80	West Virginia	51	1, 977
Michigan	4	132	Wisconsin	5	197
Minnesota	4	174	Total	3, 553	132, 191

PERSONNEL

Eppie Bell was transferred from the Smithsonian Institution to become maintenance general foreman of the National Zoological Park on May 24, 1964. John Monday, transferred from the District of Columbia Government Water Department, was appointed gardener foreman on March 15, 1964. Wilbur Banner, formerly with the Navy Department in Norfolk, Va., was appointed mason lead foreman on December 31, 1962.

During the year only three employees left the Zoo. Dr. W. T. Roth, general curator since August 7, 1961, resigned on June 30, 1964. Pvt. George McLeod, a member of the police force since September 1, 1928, retired on December 31, 1963. Lt. Earl King, appointed to the police force on August 4, 1944, retired because of disability on January 14, 1964.

The director attended the annual meeting of the International Union of Directors of Zoological Gardens in Chester, England, from September 9 to 13. At the annual conference of the American Association of Zoological Parks and Aquariums, held in Washington September 23 to 26, the director was elected president of the Association. He attended the meetings of the executive board of the American Institute of Park Executives, held in New York January 17 to 20, and a committee meeting of the AAZPA in New York on February 7. From October 30 to November 3, he was in Sumter, S.C., as consultant to city officials who plan to build a zoo in that city. On May 17, he was present at the dedication of a new feline house in City Park Zoo, Denver, Colo., and on the following 3 days he attended the Western Regional Zoo Conference in Salt Lake City, Utah. On June 21 he left for London, England, as a delegate to a symposium on the role of zoos in animal conservation. Following the conference in London he visited zoos in Munich, Turin, and Barcelona.

The director gave three radio talks and made three television appearances. He addressed the College Park (Md.) Rotary Club and also spoke at a meeting of the D.C. Veterinary Medical Association.

J. Lear Grimmer, associate director, on January 20 made a sound film to be broadcast in India over the Voice of America. On April 3 he gave a half-hour talk over WETA–TV, an educational channel, and on June 27 appeared on a film for the U.S. Information Agency. He spoke on a radio program about new animals at the Zoo (June 10) and addressed the Virginia Herpetological Society on June 6. While in India he had an opportunity to visit zoos in Delhi, Calcutta, and Guahati, as well as wildlife sanctuaries in Assam and in Sundarbans bordering the Bay of Bengal. On May 14 and 15 he attended meetings of the Inland Field Conference at the National Science Foundation, Washington, D.C.

In June Travis E. Fauntleroy, assistant to the director, visited zoos in Buffalo, Detroit, Milwaukee, Chicago, Indianapolis, Cincinnati, Columbus, Toledo, and Cleveland, observing children's zoos in particular and management operations in general.

Keeper H. Stroman appeared on a television program for the U.S. Information Agency on May 18, showing a European brown bear cub and a baby pygmy hippopotamus.

In the fiscal year 1964 the Zoo had 211 authorized positions: office of the director, 11; operations and maintenance department, which includes the mechanical division, police division, grounds division, and services division, 122; animal department, 77 (an increase of 1 night keeper); and scientific research department, 1.

POLICE DIVISION

Alterations to the topography of the Park during the past year created problems for the Zoo police, but they have made the necessary adjustments to meet the changes in flow of traffic, congested areas, dangerous locations, and changed sites of parking lots.

Four new members joined the force to replace men who retired or transferred. A new police cruiser replaced the old one, and two more horses were acquired for patrolling remote parts of the Park. Additional walkie-talkie sets facilitate direct communication between men working in widely scattered locations.

The police locker room and improved kitchen facilities were relocated to eliminate congestion in the police station and add to the comfort of the division.

AFGE Lodge No. 185 was recognized by the Smithsonian Institution as the official bargaining agent in disputes and discussion between the police department and management.

Eight letters of commendation were received, citing various officers for the courtesy, kindness, and assistance to the public.

Twenty-five officers qualified on the pistol range. The division now has seven experts, nine sharpshooters, and nine marksmen.

Lieutenant Wolfe attended the President's Conference on Occupational Safety. Captain Brink attended a seminar on management and employee relations, held at the Civil Service Commission. Lt. D. B. Bell conducted a refresher course in law enforcement. Sgt. A. L. Canter and Pvt. D. R. Bowman held classes in first aid.

During the year at the Zoo there were 1,501 traffic violations, 131 juvenile arrests, 62 criminal arrests, 106 truant children, 295 lost children, 535 minor first-aid cases, and 47 serious first-aid cases. A total of 9,395 visitors asked for information or assistance at the police station.

Through the efforts of Lieutenant Wolfe, blood procurement officer, 38 pints of blood were donated to the Red Cross Blood Bank. Thirty-seven pairs of eyeglasses, found and unclaimed, were donated to the D.C. Chapter of the Society for the Prevention of Blindness; 12 bags of clothing and miscellaneous articles, found and unclaimed, were turned over to Goodwill Industries.

Nine groups of handicapped children and 11 busloads of patients from St. Elizabeth's Hospital were escorted through the Zoo by various police officers throughout the year. On May 9 a total of 7,378 School Safety Patrol children, transported in 190 buses, visited the Park after the annual parade. Buses were parked and dispersed efficiently by the police in the limited parking areas available.

MAINTENANCE, CONSTRUCTION, AND GROUNDS

The mechanical division has the responsibility for the maintenance and repair of the buildings and facilities of the National Zoological Park. This responsibility is met by the heating and ventilating section and by the building section which, in addition to continuing maintenance, constructs new shelters, paddocks, and cages for the animals.

Considerable work was done on the monkey house this year. The wooden partitions and floors in the inside cages were rebuilt, new shifting doors installed, and inside and outside cages painted. New doors were built and installed at the building's entrance. The relocation of the Connecticut Avenue-Harvard Street road necessitated the installation of fences for visitor safety and animal protection. The small stone house for hoofed stock, back of the small mammal house, was remodeled to make it suitable for camels. One of the large alligator cages on the north end of the reptile house was remodeled and now is provided with radiant heat in the floor to make it more comfortable for the Komodo dragon. The small waterfowl pond behind the main bear line was remodeled as an exhibit area for the Komodo dragon and the Malayan monitors during the summer months.

Plumbers, electricians, carpenters, and painters are constantly at work keeping the old buildings in a decent state of repair. One of the year's tasks was to build a crate for a full-grown giraffe.

Work of the grounds division included the planting of 107 trees (some of them flowering), 63 shrubs, 78 evergreens, and various bulbs and annuals. These were planted along the new road, on banks near the shop, and throughout the Zoo lawns. Other projects included seeding new areas where contractors had been working on the road; seeding of deer paddocks, which had never before had grass; making several new flowerbeds; renewing the soil and preparing a special medium for the Komodo dragon's outdoor cage; gathering forage and grass clippings for animal food; filling in holes in lawns and walkways; and cutting of perches desired for birds and animals. The ground division also cut back branches overhanging bridle paths and cleared horse trails along the fence line; removed dead wood from 195 trees over walks, roads, and public areas; felled 92 trees that were dead or in bad condition; cut 49 unsightly stumps from Zoo lawns with the aid of a stump chipper borrowed from the U.S. Army, Cameron Station, Va.; moved snow and ice from sidewalks and building steps; sprayed bees' nests to protect the public from stings; and helped other departments in the Zoo with the Skyworker. Gifts of plants were received from the District Waterworks, Botanical Garden, Bureau of Standards, Glendale Nursery, Walter Reed Hospital, Naval Hospital, St. Elizabeth's Hospital, and the management of the annual Flower and Garden Show.

INFORMATION AND EDUCATION

The major activity of the information-education department was the continuation of signing and relabeling. During the year a total of 457 animal identification labels were completed; since the program began in October 1962, a total of eight buildings and units of the Zoo have been relabeled—the puma house, main bear dens, short bear line and ring cages, elephant house, reptile house, lion house, beaver valley, and all outdoor hoofed stock. Also produced were 221 supporting informational signs (safety signs, building signs, directional maps, etc.) and 131 other visual information projects such as maps, charts, and graphs. Four scale models were produced in conjunction with the renovation plans for the Zoo. The mechanical department assisted in framing and erecting the information signs on cages and exhibits throughout the Park.

Additional department activities during the year included dissemination of animal information by telephone and correspondence, library maintenance, and five special guided tours for groups of handicapped children, visiting schools and colleges, and foreign guests. Two such groups of interest were delegates of the Foreign Museum Professionals, sponsored by the American Association of Museums in cooperation with the Department of State, and children from the United Cerebral Palsy of Northern Virginia.

To study educational programs, labeling-exhibit techniques, and children's zoos, the zoologist visited zoos, aquariums, and museums in Texas (Dallas and Fort Worth), Arizona (Tucson), and California (San Diego, Los Angeles, and San Francisco), from October 27 to November 13. From May 20 to May 28, the zoologist toured zoos and museums in Atlanta, Ga., and Tampa and Miami, Fla., for the same purpose.

SAFETY SUBCOMMITTEE

The National Zoological Park's safety subcommittee consists of Lt. John R. Wolfe, chairman; Capt. C. E. Brink, police division; F. M. Dellar, administration office; Bert J. Barker, animal department; Reily Straw, maintenance and construction; John Monday, grounds department; and Mrs. W. M. Holden, secretary. Monthly meetings were held to suggest, discuss, and make recommendations to the director on safety improvements.

The safety subcommittee is constantly on the alert for dangers that might arise due to the construction program. Three contractors are working on separate projects at the present time. Committee mem-

bers are also vigilant in seeing that previous recommendations for safety measures are carried out.

Safety precautions taken included paving 600 feet of sidewalk, repairing potholes in roadways, installation of handrails at front and rear entrances of administration building, extending the step on the loading platform at the shop, and putting guards on power mowers.

FINANCES

Funds for the operation of the National Zoological Park are appropriated annually under the District of Columbia Appropriation Act. The operation and maintenance appropriation for the fiscal year 1964 totaled $1,597,356, which was $127,156 more than for the preceding year. The increase consisted of $25,010 to cover salary increases for general-schedule employees in accordance with Public Law 87–793; $43,260 to cover salary increases for wage-board employees; $18,560 for within-grade salary advancements for both general-schedule and wage-board employees; $21,030 to cover costs of reallocations; $8,750 for annualization of five positions established in fiscal year 1963; $4,841 to employ temporary police; $3,505 to establish one position for one-half of the year; $1,200 for miscellaneous supplies; and $1,000 for the purchase of new equipment.

Of the total appropriation, 84.5 percent ($1,349,407) was used for salaries and related personnel costs, and 15.5 percent ($247,949) for the maintenance and operation of the Zoo. Included in the latter figure were $85,150 for animal food; $23,700 for fuel for heating; $24,188 for materials for building construction and repairs; $12,473 for electricity; $12,119 for the purchase of animals; $6,933 for telephone, postal, and telegraph services; and $7,660 for veterinarian equipment and supplies. The balance of $75,726 in operational funds was expended for other items, including freight, sundry supplies, uniforms, gasoline, road repairs, equipment replacement, and new equipment.

COOPERATION

At all times special efforts are made to maintain friendly contacts with other Federal and State agencies, private concerns and individuals, and scientific workers for mutual assistance. As a result, the Zoo receives much help and advice and many valuable animals, and in turn it furnishes information and, whenever possible, animals it does not need.

Special acknowledgement is due William Taback and John Pulaski, in the office of the Dispatch Agent in New York City, and Stephen E. Lato, Dispatch Agent in San Francisco, who are frequently called upon to clear shipments of animals coming from abroad, often at times of personal inconvenience.

When it is necessary to quarantine animals coming into this country, they are taken to the U.S. Department of Agriculture's station in Clifton, N.J. During the past year Dr. H. A. Waters and Andy Goodel, two of the officials stationed there, were most cooperative in keeping the National Zoological Park informed as to the well-being of animals and birds being held there for quarantine.

Animals that die in the Zoo are offered to the U.S. National Museum. If the Museum does not need them, either as study specimens or as exhibits, they are sent on request to research workers in other institutions. Specialists at the Museum are always willing to be of help in identifying rare specimens acquired at the Zoo.

The National Zoological Park cooperated with the National Capital Parks and lent small animals to Park naturalists and to the Nature Center in Rock Creek Park for demonstration. A Taiwan cobra was lent to the New England Aquarium in Boston, Mass., for a television showing.

FRIENDS OF THE NATIONAL ZOO

The Board of Governors of the Friends of the National Zoo, at their regular monthly meeting in April, passed the following resolution:

Resolved: That the Board of Governors of the Friends of the National Zoo does hereby designate the Society's primary purpose and function to be the encouragement of a broader zoological interest and knowledge, formed particularly in the National Zoological Park. To achieve this goal, we propose that the Society promote the development of an educational service which would utilize all effective contemporary media.

Therefore, the President is authorized to establish an Educational Steering Committee, not necessarily limited in membership to present members of the Society, which would formulate and recommend to the Board programs designed to achieve these above-mentioned ends.

Since the 10-year program of capital improvements is so well under way, physically and financially, it was felt that the urgency of working in behalf of the physical rehabilitation of the Zoo was no longer great, and that the Friends could turn their energies toward developing various programs aimed at increasing and strengthening the educational potential of the National Zoological Park.

In March of this year the Friends published the first issue of their newsletter, called *Spots and Stripes*, which elicited much favorable comment. Present plans are for it to be published quarterly. The Zoo has long felt the need for this sort of publication, and staff members were glad to cooperate with the Friends in getting out the first two issues.

The annual Zoo Night was held on June 12, 1964. Approximately 250 members, with their families, were taken on a tour of the buildings, which were illuminated for the evening.

CAPITAL IMPROVEMENTS

Money in this year's Smithsonian Institution Appropriation Act amounted to $1,275,000 for the capital improvement program at the National Zoological Park. A portion of this is being used for the advance planning of the multiclimate house and aquatic mammal exhibit, preliminary studies of the sewage system, and detailed planning for the Connecticut Avenue entrance, hardy hoofed-stock and delicate hoofed-stock enclosures, and additional parking lots. A portion of the remainder is being used to construct new deer pens and new parking lots near the Connecticut Avenue entrance. The balance will be combined with fiscal 1965 money to construct the hardy hoofed-stock and delicate hoofed-stock exhibits. A portion of the money was used to build an incinerator between the shop and the heating plant. Construction of the Connecticut Avenue entrance and the hardy hoofed-stock exhibit have been combined with the delicate hoofed stock in 1965 because of delays in design due to refinements and improvements suggested by the Fine Arts Commission.

During this fiscal year work continued on the remodeling of the birdhouse and construction of a new flight cage. It is hoped that construction will be finished and the house stocked and opened to the public in late December or early January.

The relocation of the east-west access road from Connecticut Avenue to Beach Drive was completed and opened to the public. The elephant house parking lot is utilized by the visitors. Through traffic in the center of the Zoo has been completely eliminated except for Zoo vehicles. The removal of intrusive and dangerous automobile traffic has created a more leisurely and parklike atmosphere in the heart of the Zoo. As with any change, there have been some objections from the public; however, it is gratifying that many more compliments have been received than complaints.

The incinerator was constructed by the Edrow Engineering Co. It is now possible for the National Zoological Park to destroy completely all combustible waste material on the Zoo grounds. A longstanding source of embarrassingly poor housekeeping has been eliminated.

National Capital Parks, Department of the Interior, has completed the first phase of the relocation of Beach Drive, which consists of a tunnel under "Administration Hill," retaining walls, a roadbed, and new bridle trail on the east side of Rock Creek.

The Department of Sanitary Engineering of the District of Columbia installed a new 60-inch relief interceptor sewer beginning in the Zoo downstream from the wolves, near "Purcell Rock," and continuing along the west bank of the creek adjacent to an already existing sewer line crossing Beach Drive within the Zoo just below the lower

ford and continuing down through Rock Creek Park. This is part of a program of sewage improvement of the District of Columbia. Unfortunately the installation of such a large sewer necessitated the removal of most of the trees along the west bank of Rock Creek, and also the closing of the fords for many more days this year than is normal.

At various times during the year there was construction going on in five different areas of the Zoo. This caused some inconvenience to visitors and necessitated changes in their parking and established traffic patterns. These changes, however, were met with ready acceptance by the visiting public and a great deal of friendly interest by local citizens.

There was a drop in the number of organized bus groups visiting the Zoo because of the difficulty of parking buses during the construction program.

All redevelopment work is being done under the direction of the District of Columbia Department of Buildings and Grounds. Special acknowledgment is due the director of that department and his able staff.

Respectfully submitted.

THEODORE H. REED, *Director.*

S. DILLON RIPLEY,
Secretary, Smithsonian Institution.

Report on the Astrophysical Observatory

Sir: I have the honor to submit the following report on the operations of the Smithsonian Astrophysical Observatory for the fiscal year ended June 30, 1964:

DIVISION OF ASTROPHYSICAL RESEARCH

The Smithsonian Astrophysical Observatory's broad research program* this past year embraced six major areas—planetary science, meteoritic studies, cometary science, solar observation, stellar observation, and stellar theory. This division of the research program is wholly arbitrary, and the six areas are strongly interrelated.

A recent work of the director of the Observatory is an example of the amalgamation of several of these topics. For the 100th anniversary of the U.S. National Academy of Sciences, held in Washington in October 1963, Dr. Whipple was invited to present a critical summary on the history of the solar system. This lecture, considerably expanded to present his interpretation of the present state of theory of the evolution of the solar system, is now in press for the Academy's *Proceedings.* In preparing this summary, Dr. Whipple reviewed critically a number of the processes visualized as operative in the earlier stages of the evolution of our solar system. In the coming years Observatory scientists will expand their explorations in these areas.

A strong feature of the Observatory's scientific program is the ease with which a scientist investigating a particular topic may draw on experience and techniques generated by others pursuing different topics. Thus the expertise developed by the Baker-Nunn network for tracking satellites has been applied to an enlarged program of comet and flare star observations.

Planetary sciences.—With each year of mounting space activity, the other planets seem less remote. Popular response and scientific attention to planetary studies seem destined to increase as we approach the ultimate objective of manned exploration. The current studies of the earth, facilitated and stimulated by satellite observations, will eventually be repeated for the other planets. At present these geo-

*Unless otherwise noted, research is supported from Federal funds appropriated to Smithsonian Institution. The Observatory, by paying scientists' salaries, shares in the support of all research. Support from outside sources is detailed in footnotes 1–17 (p. 177).

physical investigations predominate in the planetary research activities of the Observatory and much of the scientific community.

Scientists of the Observatory, using precise satellite-tracking data from the network of Baker-Nunn cameras,[1] investigate three major geophysical topics: the detailed representation of the earth's gravitational field; the geometrical relation between points on the earth's surface; and the density and temperature of the upper atmosphere and their variations. These topics are interrelated in a way that requires that they be investigated concurrently. The director of the Observatory is responsible for initiating the coordinated attack on these problems and for monitoring their interaction with national and international programs.

As a satellite moves in its orbit, the details of its motion reflect the many irregularities in the gravitational field corresponding to the nonuniform mass distribution within the earth. The gravitational potential is conventionally represented mathematically as a series expansion in spherical harmonics. Imre G. Izsak has used a total of 26,447 precisely reduced Baker-Nunn observations of 11 objects to obtain least-squares estimates for the coefficients of tesseral and sectorial harmonics of the geopotential.[1] The method yields estimates of geophysical significance for harmonics up to the sixth degree. Evaluations of zonal-harmonics coefficients in the earth's gravitational potential up to the 14th order have been made by Dr. Y. Kozai,[1] who used precisely reduced Baker-Nunn observations of 1959 α1, 1959 Eta, 1960 ι2, 1961 Nu, 1961 σ1 and 2, 1961 $\alpha\delta$1, and 1962 $\alpha\epsilon$, inclinations of which are between 28° and 95°.

A basic computer program used in all analyses of satellite motions is the Differential Orbit Improvement program (DOI), which has been extended by Mr. Izsak, M. J. Davies, and E. M. Gaposchkin to incorporate the effects of the tesseral harmonics in the geopotential.[1]

Dr. Walter Köhnlein has analyzed the geometrical structure of the earth's gravitational field in the harmonic representation.[1] Of particular interest were the shapes of the surfaces of constant potential (geoid) and constant gravity, their Gaussian and mean curvatures, and the curvature and torsion of the plumb lines.

Theoretical studies by Dr. Chi-yuen Wang on the correlation between the satellite-derived geoid and the heat flow distribution on the surface of the earth have justified the hypothesis that the irregular undulations of the satellite geoid can be explained as the consequence of uneven thermal expansion of the earth's mantle, resulting from some heating process, perhaps an inhomogeneous distribution of radioactive heat sources.[1] Computation of variations of temperature corresponding to several proposed models of distribution of heat

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sources has led to the following conclusions: 1. The inhomogeneous layer is extended from the top of the mantle to a depth of approximately 100 to 200 km. 2. The isothermal surfaces are not simple geometrical surfaces. Temperatures on a "level surface" near the top mantle have fluctuations with amplitude of about 100° C.

The Satellite-Tracking Program is now at fruition in its geodetic objectives, not only for the earth's geopotential but also in the area of geodetic positions and the establishment of a much more precise worldwide geodetic system.[1] Several independent calculations of improved coordinates of the Baker-Nunn stations have been made during the past year. When all detailed questions in these different approaches to the problems have been resolved, a consolidated, consistent result is expected.

Over 45,000 observations from the 12 Baker-Nunn Stations were analyzed by Dr. George Veis, with the assistance of Mrs. Elizabeth Wombwell, to derive the coordinates of the stations and the absolute deflection of the vertical for seven datums.[1] Although these results are preliminary, a value of 6,378,169 meters for the semimajor axis of the earth's ellipsoid is obtained from the above derived deflections. A total of 26,447 precisely reduced photographic observations of 11 objects were analyzed by Mr. Izsak to obtain least-squares estimates for the corrections to the coordinates of the 12 camera stations. The latter calculation was made in conjunction with determinations of the coefficients for the tesseral and sectorial harmonics of the geopotential.

Using simultaneous observations of satellites from pairs of the five Baker-Nunn cameras in the Americas, Dr. Veis and Antanas Girnius have determined the directions of the lines connecting the stations with an accuracy of better than 1 second of arc. More data from simultaneous observations are now under analysis. These will allow the determination of directions in both the North American and the European datums and will permit a connection between them. Dr. Köhnlein also devised several computer programs for the adjustment of space triangulations. By using the correlation of already adjusted coordinate values, he combines a pure geometrical method and a dynamical method for a joint adjustment computation of the station coordinates.[1]

Although instrumented satellites are beginning to be important, satellite drag determined from tracking data continues to be the most productive source of information concerning the atmosphere above 200 km. Recent work at the Observatory, made possible by the *Injun 3* and *Explorer 17* satellites, includes the study of the atmosphere under conditions of low solar activity and at low heights and

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high latitudes.[1] Atmospheric density variations, which directly influence satellite drag, are interpreted as the result of temperature changes in the atmosphere. Dr. Luigi G. Jacchia generated a comprehensive model of the major temperature variations—diurnal, with solar activity, with geomagnetic activity and semiannual—for presentation at the fifth International Space Science Symposium in Florence in May. Dr. Jacchia and Jack W. Slowey found that the heating accompanying geomagnetic disturbances was greater in the auroral zones than at middle latitudes; on quiet days, however, there is no detectable latitude effect. The relation between atmospheric heating and the geomagnetic index A_p, which had been found to be nearly linear during magnetic storms, was found to depart very markedly from linearity on near-quiet days. This finding implies greater heating from this source than had been suspected before.

Plans are being drafted for a construction of quasi-static atmospheric models to be followed by dynamic models to fit the observed density data.

Techniques other than satellite tracking are also useful in high-atmosphere studies by Observatory scientists. Instrumentation augmenting the Radio Meteor Project has been developed by Dr. Mario D. Grossi to measure wind velocities at altitudes about 90 km. above ground level by collecting and processing doppler information contained in radar returns from meteor trails.[2] A network of three stations about 50 km. apart will allow at least two determinations per hour of the three components of the wind velocity vector with an accuracy of a few m sec^{-1}.

Dr. N. P. Carleton conducts a program of research that includes laboratory study of certain atomic collision processes and analysis of phenomena of the aurora and airglow in terms of the collision processes involved.[3] In the laboratory Dr. Carleton and Dr. Charles H. Dugan have been continuing study of excitation of metastable states of N_2, O_2, CO, and O by electron impact, combined with a study of subsequent collision processes involving these metastable atoms and molecules. Dr. Carleton has modified computer programs to examine the solution of two new problems: (1) the exact heating effects of the input of energetic photoelectrons into the ionosphere during the day, with application to the excitation of the dayglow, and (2) the calculation of the heating effects that could be produced in the ionosphere by a rocket-borne transmitter.

Dr. Carl Sagan and his colleagues considered several phenomena and properties of the planet Venus. The 8–13 micron limb-darkening observations of Venus from *Mariner II* and other observations have been shown to be consistent with a wide variety of models of the

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Cytherean clouds and atmosphere, including semi-infinite, purely absorbing atmospheres in radiative or convective equilibrium, and multiple-scattering cloud layers with a range of single-scattering albedos, again in radiative or convective equilibrium. Calculations in another paper show that the microwave phase effect can be explained in terms of the thermal and electrical properties of certain geochemically abundant materials at the temperatures of Venus's surface, assuming very slow planetary rotation.

Conditions on Mars have also been studied by Dr. Sagan, who has found that the wave of darkening is preferentially localized in times and locales on Mars when the mean daytime temperatures in the nuclei of the dark areas are above the freezing point of water. This result is consistent with the hypothesis that the wave of darkening is a biological response to local increases in humidity and temperature. From investigations of the question of nitrogen oxides on Mars, Dr. Sagan and his associates find that previously published observations of Mars in the infrared, visible, and ultraviolet set an upper limit to the NO_2 abundance there of about 1 mm-atm. If there is no water on Mars, the theoretical upper limit obtained from photochemical and thermodynamic equilibrium is also 1 mm-atm. With 10 microns of precipitable water in the Martian atmosphere, the NO_2 upper limit is reduced by an order of magnitude. These quantities of NO_2 are so small that it seems unlikely that the nitrogen oxides play a significant role in any observable on Mars, except possibly the blue haze.

Life may have evolved on other planets of this or other solar systems as it has on the planet earth. Dr. Sagan and his colleagues have reported the laboratory synthesis of one of the key molecules implicated in the origin of life. The molecule, adenosine triphosphate (ATP), supplies most of the energy for chemical processes in all terrestrial organisms. The work was performed in collaboration with Cyril Ponnamperuma and Ruth Mariner, at NASA's Ames Research Center. The ATP was synthesized by shining ultraviolet light on a solution of adenine, ribose, and a phosphorus compound. Adenine and ribose have previously been synthesized in similar experiments; phosphates are thought to have been present in the primitive oceans. Because of the absence of ozone from the primitive atmosphere of the earth, ultraviolet light is thought to have penetrated to the primitive oceans. The efficiency with which ATP was produced in these experiments suggests the possibility that the first organisms on earth obtained most of their energy from ATP synthesized abiologically by ultraviolet solar radiation, instead of from metabolically produced ATP, as contemporary organisms do.

Drs. Fred Franklin and Allan F. Cook have continued their study

of the structure of Saturn's rings. The dynamics of the rings are considered in a rediscussion of Maxwell's Adams Prize Essay on the stability of the rings. Photometry of rings A and B has been used to derive the optical thickness of five representative portions of the rings and the phase variation and albedo of the ring particles.

The theory of diffuse reflection from scattering layers based on the equations of radiative transfer breaks down for dense dispersions of scattered particles very large relative to the wavelength. Dr. William M. Irvine's recent examinations of the necessary correction to the usual multiple-scattering theory may relate to the situation of Saturn's rings.

Disturbances to the motion of Neptune previously attributed to the planet Pluto have been reexamined by Dr. Whipple. Other evidence indicates that Pluto is too small to produce the observed effects. Dr. Whipple has shown that a belt of comets outside the orbit of Neptune can account for the disturbances.

A long-range project of Mr. Izsak's concerns the utilization of digital computers for the complex algebraic manipulations required by analytical perturbation theories in celestial mechanics. A computer program for the analytical development of the planetary disturbing function has just been completed.[1] With the help of this program the duplication of Leverrier's classical development for Jupiter and Saturn takes about one minute of computing time.

Meteoritic science.—Many rich clues to the origin and workings of the solar system are provided by meteorites, meteoroids, interplanetary dust, and the wide range of phenomena related to them. These phenomena must be contained comfortably in any satisfactory picture of the evolution of the solar system. To exploit the diverse information offered by these bits and fragments of solid matter, the research program of the Observatory is correspondingly broad.

Fiscal year 1964 was particularly noteworthy for the meteoritic science program, because several important instrumentation complexes were completed. Large-trough antennas were added to all five remaining sites of the Radio Meteor Project[4]; the full 16-station Prairie Meteorite Network[5] went into operation; the simultaneous optical and radar networks for observing artificial meteors from Wallops Island became operational[6]; and the mass spectrometer for stable-isotope analyses of meteorites was finished.[7] Since observational data are the backbone of any scientific program, the availability of these new facilities holds promise of many productive investigations.

The addition of large-trough antennas to all the sites of the Harvard-Smithsonian Radio Meteor Project permitted the collection of reliable data on meteors smaller than any we have previously been

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able to study. Thus a long-standing objective has been met, and major results from the operation of the improved network are imminent. Using data selected from that obtained over the past several years, Drs. Gerald S. Hawkins and Richard B. Southworth have examined the physical characteristics of the small radio meteors; they find that the majority of the faint radio meteors show total fragmentation. The decrease in average velocity as the size of the bodies decreases, originally reported by Drs. Hawkins, Southworth, and B. A. Lindblad, was studied further by Kenneth Baker.[4]

The relationship between the flux of meteors incident on the earth and the observed rate of radio meteors has been determined by Dr. W. G. Elford [4] in terms of (1) the distribution law as a function of magnitude; (2) the density of meteor radiants over the celestial sphere; (3) the parameters of the radio equipment; and (4) a simple form for the ionized trail. The theory has been applied to the Harvard-Smithsonian Radio Meteor system at Havana, Illinois, and an estimate has been made of the average flux over the earth of meteors of magnitude $\geqq +12$. A provisional value of 80 $km^{-2}hr^{-1}$ has been obtained. The analysis is being extended to determine the relative density of meteor radiants over the celestial sphere.[4]

A new analysis of 413 precisely reduced meteors photographed some years ago with the Super-Schmidt cameras has been made by Dr. Jacchia, Dr. Franco Verniani, and Robert Briggs.[1] Several physical characteristics of meteor bodies, together with their interdependences, have been determined more accurately than has hitherto been possible.

Dr. Verniani's investigations of the luminous and ionizing efficiencies of meteors have been completed. These two quantities are essential for the determination of meteor masses and densities. The photographic luminous efficiency τ_p, measured with respect to kinetic energy, has been rederived from Super-Schmidt photographic data, taking fragmentation into account. The dependence of τ_p on the meteor velocity v is found to take the form $\tau_p \sim v^n$. The exponent n turns out to be 1.0 ± 0.15 for both faint and bright photographic meteors. The present evaluation of τ_p has also allowed the determination of the ionizing efficiency τ_q. Drs. Verniani and Hawkins [4] have found $\tau_q \sim v^2$. The comparison of the rates of photographic and radio meteors of about the same magnitude confirms this relation.

The Observatory has established a field operation to observe the luminosity and ionization produced by artificial meteors fired from rockets launched at Wallops Island, Virginia.[6] The Observatory now operates two Super-Schmidt cameras for this program. A third camera site will be built, and a prism will be added to an additional Super-Schmidt at the Wallops Island site. Four radar-receiving

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systems have been established at sites along the coast of North Carolina. These receivers, together with a transmitter and receiver on an ocean-going vessel, can make measurements of the ionization of artificial meteors simultaneously with the optical observations. Dr. Richard E. McCrosky is responsible for analysis of the optical data, and Drs. Hawkins and Southworth, for the radar data.

The entire 16-station Prairie Meteorite Network [5] has been in full operation since early May 1964. Dr. McCrosky is principal investigator. During the first months of operation the network obtained double-station photographs of two extremely bright objects. With magnitudes of the order of −12 and −15, both these meteors far exceed in luminosity any object on which data have previously been acquired. Their analysis is expected to yield interesting results. In each case, unfortunately, the terminal mass was judged to be too small to justify a search for the meteorite.

Dr. Cook has continued work [8] with Dr. Peter M. Millman of the National Research Council, Ottawa, and Dr. Ian Halliday of the Dominion Observatory, Ottawa, on three Perseid meteor spectra obtained at the Springhill Meteor Observatory at Springhill, Ontario, in 1957. Dr. Cook has also worked on the physics of meteors to generate a criterion for the mode of ablation, i.e., to determine whether vaporization does or does not occur and then to seek observational evidence for the action of this criterion.

During its long life the earth's surface has been hit many times by large meteorites, which have produced craters. Only a limited number of these have been recognized and studied. It is clear that appropriate effort can extend this number significantly, and the Observatory has been involved in occasional studies of craters or possible craters. Dr. Paul W. Hodge visited the Henbury Meteorite Craters and the Boxhole Crater in Australia to study the meteoritic debris in the soil surrounding them.

A field party [5] made up of Ursula B. Marvin, T. C. Marvin, and Walter A. Munn spent 16 days in August 1963 mapping and collecting samples at the site of an unusual craterlike formation in the San Luis Valley, Colo., to test the possibility that it could have resulted from the impact of a small meteorite or comet. The plane-table map shows that the "crater" is not a bowl-shaped depression in the landscape, but that the rim is a positive feature surrounding a floor that is concordant with the slope of the alluvial fan on which it lies. The search through the samples for meteorite strippings, nickel-iron spherules, or such impact products as glass or shock-produced silica minerals has not been completed, but results to date are negative.

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The tentative conclusions are that the feature is probably not an impact site but an uncommon type of sand-dune formation.

Tektites, their distribution, and possible associated impactites and earth craters pose interesting questions. Are tektites terrestrial or extraterrestrial in origin? If they are terrestrial, are there associated impact craters? Dr. Whipple has suggested that a large crater, on the order of 15 miles in diameter, may exist in the Far East area of tektite-strewn fields. Therefore Don W. Farnsworth has begun a map search for such an impact structure. He has so far examined nearly 1,000 topographic maps of Sumatra, Java, Borneo, and nearby islands. Maps showing depth to ocean bottom have been examined and contoured. Search for an impact crater continues as maps become available.

Very small particles striking the high atmosphere are stopped by atmospheric drag before they are destroyed. Larger bodies may fragment or ablate on striking the atmosphere, generating many smaller particles. Hence a rain of small particles from outside the earth is constantly falling through the atmosphere to the surface. The identification and analysis of these particles is a challenging problem.

The use of radio isotope techniques offers one means to identify material as extraterrestrial. For this purpose Dr. Edward L. Fireman, working with Chester C. Langway of the Army Cold Regions Research Laboratories, has collected and analyzed dust from melted snow deep within the Greenland ice sheet. Results from this study indicate that the exposure age of silicates in dust is less than 10,000 years.[9]

Mrs. Ursula B. Marvin has made comparative studies of the mineralogy, chemical composition, and physical properties of black spherules from the Greenland ice cap and industrial black spherules produced by welding operations.[10] Results showed that weld spatter sometimes duplicates a type of black spherule, consisting of iron oxide (magnetite) with less than 1 percent of manganese, that is found in the Greenland ice and has been reported from many other environments where researchers have sought extraterrestrial dust. The most common weld spatter, however, is metallic iron or nickel-iron that can be distinguished from cosmic dust by a high content of chromium. This work was done in collaboration with Mr. Langway.

Collections of small particles have also been made on Observatory collectors flown on a U–2 at high altitudes by the U.S. Air Force, and on a B–52 by the NASA Flight Research Center, both at Edwards Air Force Base, California. These collections have been analyzed by Dr. Frances Wright and Dr. Hodge. They have also examined

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material from polar ice cores in search for extraterrestrial particles and have collected particles on the slopes of the Arizona Meteorite Crater for analysis and comparison with other matter that now seems to be extraterrestrial.

A particular problem has been the isolation of volcanic particles, which may be confused with extraterrestrial material. To better characterize volcanic particles, Dr. Wright is examining collections made by personnel from the Baker-Nunn Stations: samples from Kilauea Iki 1959 eruption, collected by D. V. Mechau; samples from Irazu 1963 eruption, collected by Ron La Count; and samples from Ubinas 1954 eruption, collected by A. Oakes.

Drs. Wright and Hodge have sampled these volcanic dust deposits to search for and analyze microscopic spherules that might possibly be similar to the supposed meteoritic spherules found in polar ice sediments. In the size range of 10 to 100μ, approximately 2×10^{-5} of volcanic particles are perfect or nearly perfect spherules, and 2×10^{-3} are rough magnetic spheroids. In composition they are similar to only a few of the polar glacier particles the two have analyzed. They have concluded that since the numerical ratio of spherules to irregular particles for the volcanic dust is so much different from that for the ice sediments, a volcanic origin for the latter seems impossible. Therefore a meteoroidal origin for the arctic and antarctic spherules is the most reasonable hypothesis.

Another place where cosmic dust might be expected to accumulate is the sediment on the ocean floor. Dr. Craig M. Merrihue is exploring this possibility. A mass-spectrometric search for extraterrestrial material in a magnetic separate from a modern Pacific red clay revealed the presence of He^3 and an argon isotope anomaly, suggesting the presence of cosmic dust. The cosmic gases are not cosmogenic because the isotope pattern does not resemble that expected from cosmic-ray-induced reactions. It appears that the most abundant magnetic component of cosmic dust is saturated with gases picked up from the solar wind. A computer program has been assembled to solve the diffusion equation for gases from spheres, assuming an arbitrary nonuniform initial gas profile. This program will permit accurate determinations of diffusion constants and activation energies for meteoritic minerals.

The Observatory's interest in dust goes beyond the earth's atmosphere. The joint research of Drs. Giuseppe Colombo and Don A. Lautman, with Irving Shapiro of the M.I.T. Lincoln Laboratory, concerning the concentration of cosmic dust around the earth has established that the density of dust in the vicinity of the earth can be enhanced by a factor of nearly 10^4 over that in the zodiacal cloud,

provided that the initial velocities with respect to the earth are small (about 1.5 km sec^{-1}). The trapping mechanism consists of an initial encounter with the earth's atmosphere followed by conversion to a long-lifetime orbit by radiation pressure. Drs. Colombo and Lautman have found that long-lifetime orbits of particles ejected from the moon cannot contribute significantly to the cloud, nor can particle breakup, since the drag pressure at the relatively high capture altitudes is not high enough to break the particles.

The particles responsible for the zodiacal light are concentrated near the plane of the ecliptic. Dr. Southworth has performed a calculation combining the space-density distribution of the zodiacal dust particles (as observed in the zodiacal light, and as theoretically predicted from the Poynting-Robertson effect) with the observed reddening of the Fraunhofer corona (which is sunlight diffracted by the particles), showing that the mean radius of the observed particles exceeds 15 microns. Some invisible submicron particles may also be present, but their total mass will be negligible compared to that of the larger particles.

Dr. Charles Whitney has obtained laboratory evidence confirming the suggestion that interstellar bands are produced by resonant absorption in small grains. Experimental work confirms the presence of the band for Na grains, and theory shows that such grains, when coated with ordinary ice, will produce an absorption just at the astronomically observed wavelength.

Meteorites, solid bodies from space that survive the plunge through the earth's atmosphere, warrant careful attention, since they are the only samples yet available of extraterrestrial material. It is fruitful to study their mineralogy, crystal structure, metallurgy, chemical composition, isotope distribution, and other physical properties.

In her continuing mineralogical studies Mrs. Marvin has established zircon as a meteoritic mineral by its positive identification in the Vaca Muerta mesosiderite and the Toluca iron meteorite.[10] Zircon, because it concentrates uranium, thorium, hafnium, and rare earths, is a mineral of choice for age determinations and measurements of Zr/Hf ratios and rare-earth distribution in meteorites. The character and mode of occurrence of zircon in Vaca Muerta and Toluca were studied in detail in collaboration with Cornelis Klein, of the Harvard University Department of Geological Sciences, who determined chemical compositions by means of electron-probe microanalyses.

During the past year Dr. Joseph I. Goldstein completed a metallurgical study of Widmanstätten patterns in metallic meteorites. The object of the project was to establish the roles of pressure, tempera-

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ture, and time in the formation of these patterns. A method of analysis using the method of finite differences was developed for the diffusion-controlled growth of the Widmanstätten patterns. As necessary inputs to the growth analysis, the interdiffusion coefficients for the Fe-Ni system, as a function of pressure, temperature, and composition, were measured, as were the diffusion coefficients in both the α and γ phases. The Fe-Ni phase diagram was also redetermined at temperatures above 500° C. Dr. Goldstein proposes two alternative models for the origin of meteorites in which the Widmanstätten pattern formed at low pressures.

Dr. Matthias F. Comerford has initiated a program to investigate defect structures in meteorites and micrometeorites. An attempt is being made to relate the substructure observed in extraterrestrial objects to the thermomechanical procedures required to produce similar structures in laboratory alloys. The environmental effects of both pressure and temperature upon the kinetics of nucleation and growth of these defect structures can be examined in some detail. Preliminary results indicate that both effects are present and may act in opposing ways.

Dr. Fireman and his associates conduct a broad program of research to measure cosmic-ray-produced radioactive and stable isotopes in meteorites, in recovered satellites, in dust collections from the polar regions, and in deep-sea sediments. In this program one must constantly improve and maintain low-level counting equipment and other types of analytical apparatus. The group has determined the time various meteorites were exposed to cosmic rays. The youngest is the Farmington meteorite, which was exposed for only 10,000 years; the oldest stony meteorite is Norton County, exposed for about 400,000,000 years. Results on recovered satellites indicate that in addition to cosmic rays there are isotope effects produced by Van Allen particles and solar flares. These effects are quite different from cosmic-ray effects.

An important advance was made during the past year when James C. DeFelice and Dr. Fireman obtained sufficient material to measure the short-lived argon-37 in the whole-rock, magnetic, and nonmagnetic phases of the recently fallen chondrite Peace River. Although the radioactive contents are similar to those of other newly fallen chondrites, the ratio of argon-37 to argon-39 is somewhat lower than they have previously observed. Also, its carbon-14 is lower. In another analysis, the cosmic-ray exposure age of the Pribram meteorite was found to be identical to the value of the exposure age obtained for the Bruderheim fall, which is typical for chondrites. The tritium, argon-

39, and carbon-14 contents are similar to those obtained for other stony meteoroids.

Earlier measurements of tritium in satellite fragments have been extended by Dr. David Tilles and Mr. DeFelice, who have obtained upper limits for the tritium content of *Discoverer 14* and for the amount of tritium in a trapped state in August 1960. These measurements, combined with measurements previously reported in other satellites, have given evidence for an increase of at least an order of magnitude in trapped tritium flux in less than 4 months and a decrease of at least an order of magnitude in less than 7 months. Such time variations are believed to have been caused by direct injection of solar-flare tritons into the Van Allen belts in November 1960.

Dr. Merrihue's analysis of data on xenon and krypton from minerals and chondrules from the Bruderheim meteorite indicates that chondrules, enriched in Xe^{129} yet depleted in xenon, are the most primitive material yet studied and reflect an early high-temperature origin. Based on a Xe^{129}-xenon correlation, the minerals appear to be an equilibrum aggregation. The difference between meteoritic and terrestrial xenon can be attributed to a fast proton irradiation of meteoritic material and the accumulation in meteorites of fission xenon, possibly from Pu^{244} spontaneous fission.

Dr. Merrihue has devised a method of trace-element determinations by mass spectrometry of neutron-irradiated samples. Preliminary results, based on data collected at Berkeley, were obtained for U^{235}, Se, Te, I, Br, and Cl, and also for the Br^{79}/Br^{81} ratio, which appears to be anomalous in meteorites. Also, a new method of potassium-argon dating, applicable to minute samples, has been established, based on A^{40}/A^{39} ratios in neutron-irradiated samples in which A^{39} is produced by the K^{39}(n,p) reaction. Thus both potassium and radiogenic argon are determined in the same sample, and a correction for air contamination can be applied using the measured A^{36}. This represents a considerable improvement over conventional methods.

The rare-gas mass spectrometer has been completed by Dr. Tilles and his associates.[7] As a first application of the instrument, the group plans searches of deep-sea sediment for evidence of material of extraterrestrial origin. Similar searches are planned in particulate matter from Greenland ice, collected by Dr. Fireman and Mr. Langway. The major research emphasis with this spectrometer will be on studies of meteoritic samples—isotopic composition and amounts of all noble gases in separated phases of meteorites.

From the theoretical aspect, Dr. Henri E. Mitler is studying the effects of cosmic-ray bombardment on meteorites. Quantitative analysis of radionuclides produced can lead to estimates of the preatmos-

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pheric size of the meteorite and of the proton flux to which it has been subjected.

Cometary science.—Comets and their associated phenomena are intimately related to other aspects of the solar system, such as zodiacal dust, micrometeorites, and evolution of the planets. Cometary investigations hence constitute a vital link in the Observatory's overall research program.

A study by Dr. Whipple of the secular variation in the absolute brightnesses of comets leads to the possibility that several of the known periodic comets may disappear within the coming decade. The observational rediscoveries of the periodic comets suggest that these calculations are more pessimistic with regard to the lifetimes of comets than is justified; nevertheless, the predictions should serve a useful purpose in stimulating search for the rediscovery of old comets and in clarifying the question concerning the actual decay processes whereby comets do, indeed, cease to be visible.

Dr. Whipple, in the study mentioned earlier, has also discussed the evidence that a thin belt of comets probably remains in a plane not far from the mean plane of the planets, but outside the orbit of Neptune. Such a belt of comets can account for disturbances of Neptune's motion.

The utilization of the Baker-Nunn cameras for comet observations has been expanded.[12, 1] Using photographs thus obtained, the Observatory is pursuing three objectives: determination and understanding of the motion of comet tails; photometry of comets; and time-lapse motion pictures to document the changes in a comet and its tail with time.

The research on tail motions is guided by Daniel Malaise,[13] who has previously observed that the direction of the tail of a comet may oscillate significantly about the line directed through the comet away from the sun. The explanation of this phenomenon is not clear, but it may be related to some characteristic of the solar wind. Baker-Nunn photographs are an excellent source of the observational data required to pursue this topic. Data obtained during the past year are being analyzed.

The photometric investigations are the responsibility of Dr. Southworth. For this purpose, defocusing lenses have been sent to a number of the stations. An unresolved question in cometary astronomy is whether comet magnitudes do indeed change in correlation with solar activity, as some investigators have reported. A study of this question is one of several investigations based on the photometric data.

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In conjunction with the icy-conglomerate model of a comet, Dr. Whitney reexamined the theory of heat transfer within glaciers. He showed that radioactive transfer can be appreciable and can significantly influence measured temperatures in glaciers. Dr. Whitney, Dr. Charles A. Lundquist, and Douglas Pitman have initiated laboratory work to elucidate the transfer of heat and mass within porous, subliming matrices such as snow or frosty sand. Preliminary experiments confirm that this work will be highly valuable for insight into comet phenomena.

Solar observations.—Information about solar phenomena may be acquired by relatively direct or by indirect observational techniques. Heating of the earth's atmosphere or oscillations in the direction of a comet's tail are examples of indirect means of gleaning solar data. The Observatory is also involved in more direct measurements.

Dr. Leo Goldberg directs a broad program of solar-oriented research, mostly under the auspices of Harvard College Observatory, but partly within the research program of the Astrophysical Observatory. An important part of Dr. Goldberg's program concerns the preparation of solar spectrometers for rocket and satellite flights.[14]

A model of the Harvard spectrometer for Orbiting Solar Observatory B was flown in an Aerobee high rocket from White Sands, New Mexico, on September 6, 1963. Three full scans and part of a fourth were obtained of the solar spectrum between 1350 and 500 A. Good records were obtained of the emission lines and of the Lyman continuum. Dr. Robert W. Noyes of the Astrophysical Observatory assisted in the reduction of the data from this experiment.

The flight model for the OSO–B spectrometer was integrated into the spacecraft at Ball Brothers Research Corporation in Colorado and subsequently delivered to Cape Kennedy for final testing and preparation for flight. A disastrous accident during spin-balance testing, in which the third stage of the rocket to which the satellite was attached ignited, caused the destruction of the entire payload. A spare instrument now being calibrated will be integrated into a new spacecraft during the next fiscal year. Dr. Noyes supervised the setting up of a "Quick Look" Data System, by which data from experiments aboard the Orbiting Solar Observatories will be acquired by Harvard-SAO in decoded, legible form within a short time of the satellite's pass over a ground station, thus permitting near-real-time control of the experiment.

Designs are currently being prepared[15] for an improved version of the spectrometer capable of one arc minute resolution on the disk, which will probably be flown about 1966.

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Observations made at the Kitt Peak National Observatory concerning magnetic fields in the solar photosphere have been analyzed by Dr. Noyes. These observations yielded a definite correlation between photospheric velocities and magnetic fields, in the sense that the highest magnetic fields (about 50–75 gauss) found in quiet regions tend to occur in regions where material is moving downward (with velocities of about 0.2 km sec^{-1}). This has been interpreted as a result of convective sweeping of magnetic fields toward the downward-descending periphery of the large convective cells (supergranulation) which cover the surface of the quiet sun.

Dr. Giovanni Fazio has reduced gamma-ray detector data from 1,000 orbits of Orbiting Solar Observatory I.[16] These reductions have shown no evidence of gamma rays with energy greater than 50 million ev from the sun, even during solar flares, with an upper limit of the order of 10^{-3} photons/cm^2 sec. Likewise, no evidence was found for celestial sources of primary gamma rays. The sensitivity of the detector was limited by background radiation.

The possibility of detecting neutrinos from the sun is a lively topic of discussion in astrophysical circles. Some authors suggest that this can be accomplished by using the reaction in which a solar ν_e combines with a Cl^{37} nucleus to give Ar^{37} and an electron. The radioactive gas Ar^{37} may be detected by counting techniques. The Observatory has laboratories equipped to do this counting, as Ar^{37} is one of the radioactive isotopes analyzed in meteorites. Since the ν_e reaction cross section with Ar^{37} is extremely low, vast quantities of Cl^{37} must be used. Since Ar^{37} can also be generated by cosmic-ray-induced rections, the experiment must be performed under conditions of extreme radiation shielding—say deep in the earth. Dr. Lundquist has suggested that commercially pumped brine wells might meet these requirements, if the Ar^{37} from the chlorine-rich brine could be measured. Dr. Mitler has made a study of the relative amounts of Ar^{37} generated by the solar neutrino reaction and by other undesired reactions. The practical implementation of the experiment is being studied.

Stellar observations.—A feature of current astrophysics is the rapid expansion of observational possibilities into previously inaccessible parts of the electromagnetic spectrum and to radiation other than electromagnetic. This has been accomplished in part by carrying instruments above the absorption of the atmosphere. New technology has also contributed to the enlarged observational capabilities. Comparison and correlation of data from widely spaced frequencies have also proved to be powerful procedures.

An example of correlated observations at quite different frequencies is the study of flare stars.[1] During preagreed time intervals, the

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Observatory employs its network of Baker-Nunn cameras to photograph a flare star repeatedly. The probability of successful observation is good since several of the cameras can be used simultaneously. During the same interval, one of several radio telescopes cooperating in the program continuously observes the same flare star. The resulting records are searched for nearly simultaneous optical flares and sudden increases in radio signal. During the past year about 180 hours of combined observations have been made. Correlations previously found to exist between faint optical flares and radio events were confirmed by several major events.

The continuing cooperative effort with Sir Bernard Lovell of the Jodrell Bank Experimental Station, England, and Dr. Whipple and Leonard H. Solomon of the Astrophysical Observatory has led to further new evidence concerning optical flares and radio flares on peculiar dwarf stars, such as UV Ceti. A distinction between two types of event has been made, with at least one analogy to solar phenomena being drawn. Further, the coincidence in time between optical and radio flares shows that the velocity of light is constant to better than one part in 2×10^6 over a range in wavelength exceeding a factor of 2×10^6. Similar joint programs are being pursued with the Division of Radiophysics, Commonwealth Scientific and Industrial Research Organization, Sydney, Australia, and the Arecibo Ionospheric Observatory of Cornell University.

Project Celescope,[17] the satellite project to use television techniques to survey the ultraviolet magnitude of stars, has finished its developmental phase with completion of the prototype instrument. The project next enters the critical phase during which the prototype undergoes extensive environmental testing, and the instrument for flight on an Orbiting Astronomical Observatory is fabricated to the proven prototype design. Overall aspects of this challenging undertaking have engaged the attention of Dr. Whipple, Dr. Lundquist, and Project Scientist Dr. Robert Davis. The procedures for absolute calibration of the four ultraviolet television photometers have been established by Dr. Davis and Mr. Malaise. Preparations for automated data reduction and analysis are coordinated by Dr. Owen Gingerich.

At wavelengths still shorter than ultraviolet light, projects are underway at the Observatory to measure X-rays and γ-rays from astronomical sources. The most exciting experiment now in progress is an attempt by Dr. Fazio and Dr. Henry Helmken of the Observatory and Dr. D. Hill of M.I.T. to detect γ-rays with energy greater than 10^{12} ev from the radio galaxy Cygnus A and from the quasi-stellar radio sources. A large (28 ft. square) fixed parabolic mirror in conjunction with a steerable plane mirror (40 ft. square) is being used to detect the

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Čerenkov light resulting from charged-particle showers in the atmosphere. One possible origin of these showers is extraterrestrial gamma radiation. In the experiment an increase in the number of showers as a source transits the sensitive cone of the mirror would indicate the emission of gamma radiation by the source. In preliminary trials Čerenkov light was detected, and results indicate that this device should provide the most sensitive detector thus far in the search for gamma radiation. The mirror system is part of the solar furnace at the U.S. Army Laboratories, Natick, Mass. The Army has provided use of the instrument and technicians during these experiments.

The feasibility of using a spark chamber in conjunction with a television recording system to detect primary gamma rays was exhibited in the laboratory, and a high-altitude balloon experiment using this detector is in preparation. A series of spark chambers was constructed and evaluated, and a final design was chosen. A television camera (vidicon) was used to observe spark patterns of cosmic-ray particles in the chambers. The vidicon picture was recorded on 16 mm film by a kinescope recorder and also transmitted by radio and recorded. In its ultimate form, this instrumentation can be adapted for satellite use to measure the flux of primary gamma rays and to determine their arrival direction and energy.

Dr. Comerford and Dr. Fazio are using laboratory X-ray apparatus to evaluate techniques such as reflection and scattering for the collection and detection of radiation from distant sources and to aid in the design and construction of devices to implement these techniques. Currently, the aim is not to map the sky, but to look carefully at discrete sources in the hope of resolving some of the uncertainties about their nature.

Returning to the less exotic but ever-important visible portion of the spectrum, Drs. Wright and Hodge have completed the Atlas of the Large Magellanic Cloud. Heretofore it has been the custom for scientists who have identified and studied certain objects in the Large Magellanic Clouds to publish identifications in the form of coordinates on one of three different coordinate systems. The experience of most scientists with this method of identification has been very unsatisfactory, as the coordinates are inadequate, especially for stellar objects. Ambiguity arises because of the crowded nature of the star fields and the difficulty of establishing the coordinate systems on different plates with different scales and distortions. A further hindrance to progress in the study of the Magellanic Clouds is the lack of any central source of information on objects that have been identified and studied. There have been much confusion and duplication in identification of variable stars, star clusters, and emission regions.

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Hence this Atlas presents a photographic bibliography of past discoveries so that identification can be made quickly and accurately. The photographic plates taken expressly for the Atlas have now been completed. They were taken with the Schmidt telescopes at the Boyden and Mt. Stromlo Observatories. Two sets of plates were taken, one with a yellow filter and one with a blue filter. From these, 160 charts size 11 by 11 inches have been made. The charts made from plates taken with a blue filter have identified on them all published verifiable variable stars, over 2,000 in number, while the other charts have identified on them all of the NGC objects, all star clusters, and all emission objects for which positions have been published. In the process of identifying past discoveries, 500 new star clusters were identified.

The SAO Star Catalog, initially reduced in the FK–3 system, has been converted to the FK–4. All the preparatory work for publication in book form has been completed.[1] Dr. Veis and Mrs. Katherine Haramundanis have begun the groundwork for a possible future enlargement by compiling a bibliography of star catalogs and references pertaining to them; determining approximate orientation angles for 1,231 galaxies; and compiling a catalog of about 2,500 discrete radio sources.

Stellar theory.—The Astrophysical Observatory has become a recognized leader in the application of modern electronic computers to stellar models. In January 1964 the Observatory was host to an informal 3-day international Conference on Model Stellar Atmospheres, which provided an opportunity for workers in this field to discuss their current researches. The conference was convened by Dr. Whitney and his associates.

Extensive calculations of model stellar atmospheres are being continued by Drs. Eugene H. Avrett and Stephen E. Strom.[11] The grid of models calculated during the past year has been very successful in establishing an improved effective temperature scale for early-type stars. The effects of individual lines and of line blanketing are now being incorporated into the computer program. The first phase of investigation of line formation under conditions of noncoherent scattering has been completed. Solutions were obtained for the frequency-independent line source function for a two-level atom. Of greater importance, the necessary mathematical techniques have been developed for the solution of a wide variety of line-transfer problems.

Dr. Strom has investigated the validity of model stellar atmospheres by means of comparing predicted continuous fluxes and spectral lines with the corresponding observed quantities. He obtained

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many of the observations at Harvard's Agassiz Station. The continuous flux and Hδ, Hγ, and Hβ profiles for Vega were predicted remarkably well by a model atmosphere that included opacities caused by the blended wings of the higher Balmer and Lyman lines. The effective temperature of the model that best reproduced the observations matched that derived from recent measurements of this star's radius.

Dr. Gingerich has investigated the role of opacities from metals in stellar atmospheres,[11] finding good agreement between a predicted model and the solar rocket ultraviolet observations, and also showing that such opacities must be considered even in much hotter stars, such as Sirius, which probably has anomalously high metal abundances. In the work with S. S. Kumar on cool stars, with effective temperatures from 2,500 to 4,500°, he found unusually sharp maxima in the infrared spectrum near 16,500 A, which have been partially confirmed by the Princeton Stratoscope balloon observations. Electron and Rayleigh scattering has been incorporated into a stellar atmosphere computer program, both for the cool stars and for hotter stars. With this program David Latham has been able to show that the introduction of convection into a consistent nongray solar model has little effect on the overlying temperature structure, and no effect on the visible spectrum.

Dr. Wolfgang Kalkofen is developing a model whose aim is to predict the radiation from variable stars.[11] This involves the calculation of the radiation field emerging from a medium that departs from local thermodynamic equilibrium, and that is in motion, with a velocity dependent upon position in the medium.

Drs. Colombo and Whitney are studying a nonlinear autonomous system with two or three degrees of freedom. This system is chosen to simulate the mechanics of a pulsating star.

Dr. Mitler has made theoretical study of the isotope abundances of the light elements. He shows that the observed abundances of Li, Be, and B can be explained by their spallation in small, prototerrestrial bodies. He considers spheres of arbitrary composition and radius irradiated by protons and finds that the present-day proton flux is too soft to give the desired results reasonably, and that a mean proton energy of 300 mev is necessary to get the observed isotopic ratios. The results are not sensitive to the composition, and he can obtain the measured Li, Be, and B abundances by taking dry silicate spheres of about 14 m radius for the prototerrestrial bodies, 140 m for the protoasteroidal bodies.

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[1] Supported by grant NsG 87/60 from the National Aeronautics and Space Administration.

[2] Supported by contract AF 19(628)–3248 with the U.S. Air Force.

[3] Supported by contracts AF 19(628)–2949 (now completed) and AF 19(628)–4203 with the U.S. Air Force.

[4] Supported by grants G 20135 and GP 388 from the National Science Foundation to Harvard University and by contract NASr–158 between the National Aeronautics and Space Administration and Harvard University.

[5] Supported by grant NsG 291–62 from the National Aeronautics and Space Administration.

[6] Supported by research grant NsG 536 from the National Aeronautics and Space Administration.

[7] Supported by grant NsF 16067 from the National Science Foundation.

[8] Supported by contract AF 19(604)–5196 between the U.S. Air Force and Harvard University.

[9] Supported in part by grant NsF 16067 from the National Science Foundation.

[10] Supported in part by grant NsG 282–63 from the National Aeronautics and Space Administration to Dr. Clifford Frondel of Harvard University.

[11] Supported by grant GP 940 from the National Science Foundation.

[12] Supported by grant GP 2999 from the National Science Foundation.

[13] Research sponsored by fellowships from NASA, Fonds National de la Recherche Scientifique, Belgium, and European Preparatory Commission for Space Research.

[14] Supported by contract NASw 184 between the National Aeronautics and Space Administration and Harvard University.

[15] Supported by grant NsG 438 from the National Aeronautics and Space Administration to Harvard University.

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WOOD, J. A. On the origin of chondrules and chondrites. Icarus, vol. 2, pp. 337–401, 1963.

WRIGHT, F. W. *See* Hodge and Wright.

WRIGHT, F. W.; HODGE, P. W.; AND LANGWAY, C. C., JR. Studies of particles for extraterrestrial origin. I. Chemical analyses of 118 particles. Journ. Geophys. Res., vol. 68, pp. 5575–5587, 1963.

The Special Reports of the Astrophysical Observatory distribute catalogs of satellite observations, orbital data, and preliminary results of data analysis prior to journal publication. Numbers 127 through 156, issued during the year, contain the following material:

No. 127, July 8, 1963
Attitude determination from specular and diffuse reflection by cylindrical artificial satellites, by R. H. Giese.

No. 128, July 10, 1963
Ultraviolet synthesis of adenosine triphosphate under possible primitive earth conditions, by C. Ponnamperuma, C. Sagan, and R. Mariner.

No. 129, July 15, 1963
Laplace coefficients and their Newcomb derivatives, by I. G. Izsak.

No. 130, July 17, 1963
Catalogue of satellite observations: Satellites 1958 α (*Explorer 1*), 1959 $\alpha 1$ (*Vanguard 2*), 1959 η (*Vanguard 3*), and 1959 $\iota 1$ (*Explorer 7*), for July 1–Dec. 31, 1962; Satellite 1958 $\beta 2$ (*Vanguard 1*) for Sept. 22–Oct. 18, 1962; and Satellite 1960 $\gamma 2$ (*Transit 1B*) for Sept. 29–Oct. 24, 1962, prepared by B. Miller.

No. 131, July 18, 1963
Catalogue of satellite observations: Satellites 1960 $\iota 1$ (*Echo 1*), 1960 $\iota 2$ (*Echo 1 rocket*), and 1960 $\xi 1$ (*Explorer 8*) for July 1–Dec. 31, 1962, prepared by B. Miller.

No. 132, July 19, 1963
Catalogue of satellite observations: Satellites 1961 $\delta 1$ (*Explorer 9*), 1961 o1 (*Transit 4A*), and 1961 o2 (*Injun Solar Radiation 3*) for July 1–Dec. 31, 1962; Satellite 1962 $\alpha\epsilon 1$ (*Telstar 1*) for July 10–Dec. 31, 1962; Satellite 1962 $\beta\lambda 1$ (*Explorer 15*) for Nov. 2–Dec. 20, 1962; Satellite 1962 $\beta\mu 1$ (*Anna 1B*) for Nov. 1–Dec. 31, 1962; Satellite 1962 $\beta\nu 1$ (*Relay 1*) for Dec. 15–31, 1962; and Satellite 1962 $\beta\chi 1$ (*Explorer 16*) for Dec. 16–21, 1962, prepared by B. Miller.

No. 133, August 16, 1963
The determination of absolute directions in space with artificial satellites, by G. Veis.

No. 134, September 12, 1963
On the distribution of surface heat flows and the second order variations in the external gravitational field, by C. Y. Wang.

No. 135, September 16, 1963
Formulae and tables for the computation of lifetimes of artificial satellites, by L. G. Jacchia and J. Slowey.

No. 136, September 17, 1963
Atmospheric heating in the auroral zones: A preliminary analysis of the atmospheric drag of the *Injun III* satellite, by L. G. Jacchia and J. Slowey.

No. 137, September 30, 1963
Catalog of precisely reduced observations: Satellite 1960 $\gamma 2$ (*Transit 1B*) for May 7–19, 1960; Satellite 1960 $\iota 1$ (*Echo 1*) for Aug. 12–31, 1960; and Satellite 1961 $\delta 1$ (*Explorer 9*) for July 1–Dec. 31, 1961, prepared by P. Stern.

No. 138, October 1, 1963
Catalog of precisely reduced observations: Satellites 1959 $\alpha 1$ (*Vanguard 2*), 1959 η (*Vanguard 3*), 1960 $\iota 2$ (*Echo 1* rocket), and 1961 $\delta 1$ (*Explorer 9*) for Jan. 1–June 30, 1962, prepared by P. Stern.

No. 139, October 15, 1963
Optical radar results and meteoric fragmentation, by G. Colombo and G. Fiocco.

No. 140, January 24, 1964
Construction of Newcomb operators on a digital computer, by I. G. Izsak, J. M. Gerard, R. Efimba, and M. P. Barnett.

No. 141, January 30, 1964
Satellite orbital data: Satellites 1959 $\alpha 1$ (*Vanguard 2*), 1959 η (*Vanguard 3*), 1960 $\iota 2$ (*Echo 1* rocket), and 1961 $\delta 1$ (*Explorer 9*) for Jan. 1–June 30, 1962; Satellite 1960 $\beta 1$ (*Tiros 1* rocket) for Apr. 12–May 26, 1960; Satellite 1960 $\beta 2$ (*Tiros 1*) for Apr. 12–Sept. 15, 1960; Satellite 1960 $\iota 1$ (*Echo 1*) for Aug. 14–30, 1960; Satellite 1961 o1 (*Transit 4A*) for Aug. 11, 1961–June 25, 1962; and Satellite 1961 o2 (*Injun 3*), for Aug. 11, 1961–June 29, 1962, prepared by I. G. Izsak.

No. 142, January 31, 1964
Satellite orbital data: Satellites 1958 α (*Explorer 1*), 1959 $\alpha 1$ (*Vanguard 2*), 1959 η (*Vanguard 3*), 1959 $\iota 1$ (*Explorer 7*), 1960 $\iota 1$ (*Echo 1*), 1960 $\xi 1$ (*Explorer 8*), and 1961 $\delta 1$ (*Explorer 9*) for Jan. 1–Apr. 1, 1963, prepared by I. G. Izsak.

No. 143, February 3, 1964
Inhomogeneous distribution of the radioactive heat sources. I. Theory, by C. Y. Wang.

No. 144, February 10, 1964
Geodesics on an equipotential surface of revolution, by W. Köhnlein.

No. 145, February 17, 1964
On the luminous efficiency of meteors, by F. Verniani.

No. 146, February 24, 1964
On the visual tracking of two bright satellites from C-130-type aircraft, by R. C. Vanderburgh.

No. 147, February 27, 1964
Catalog of precisely reduced observations: Satellite 1960 $\beta 1$ (*Tiros 1* rocket) for Apr. 5–June 1, 1960; Satellite 1960 $\beta 2$ (*Tiros 1*) for Apr. 5–Sept. 21, 1960;

and Satellites 1961 o1 (*Transit 4A*) and 1961 o2 (*Injun Solar Radiation 3*) for Aug. 5, 1961–Dec. 31, 1962, prepared by P. Stern.

No. 148, February 28, 1964

Catalog of precisely reduced observations: Satellites 1959 α1 (*Vanguard 2*), 1959 η (*Vanguard 3*), 1960 ι2 (*Echo 1* rocket), and 1961 δ1 (*Explorer 9*) for July 1–Dec. 31, 1962; Satellite 1961 δ1 (*Midas 4*) for Mar. 9–Dec. 31. 1962; and Satellite 1962 $\alpha\epsilon$1 (*Telstar 1*) for July 13–Dec. 31, 1962, prepared by P. Stern.

No. 149, April 15, 1964

Long-period effects in nearly commensurable cases of the restricted three-body problem, by J. Schubart.

No. 150, April 22, 1964

The temperature above the thermopause, by L. G. Jacchia.

No. 151, May 5, 1964

A catalog of positions and proper motions of 258,997 stars for the epoch and equinox of 1950.0, by the Staff of the Smithsonian Astrophysical Observatory.

No. 152, June 15, 1964

Temperature variations in the upper atmosphere during geomagnetically quiet intervals, by L. G. Jacchia and J. Slowey.

No. 153, June 16, 1964

Catalogue of satellite observations: Satellites 1958 α1 (*Explorer 1*), 1959 α1 (*Vanguard 2*), 1959 η1 (*Vanguard 3*), and 1959 ι1 (*Explorer 7*) for Jan. 1–June 30, 1963, prepared by B. Miller.

No. 154, June 17, 1964

Catalogue of satellite observations: Satellites 1960 ι1 (*Echo 1*), 1960 ι2 (*Echo 1* rocket), 1960 ξ1 (*Explorer 8*), and 1961 δ1 (*Explorer 9*) for Jan. 1–June 30, 1963, prepared by P. Stern.

No. 155, June 18, 1964

Catalogue of satellite observations: Satellites 1961 o1 (*Transit 4A*), 1961 o2 (*Injun Solar Radiation 3*), 1962 $\alpha\epsilon$1 (*Telstar 1*), and 1962 $\beta\mu$1 (*Anna 1B*) for Jan. 1–June 30, 1963; Satellite 1962 υ1 (*Cosmos 5*) for Mar. 11–Apr. 30, 1963; Satellite 1962 $\beta\tau$2 (*Injun 3*) for Jan. 16–June 30, 1963; Satellite 1962 $\beta\upsilon$1 (*Relay 1*) for Jan. 4–June 30, 1963; Satellite 1963 9A (*Explorer 17*) for Apr. 6–June 24, 1963; and Satellite 1963 13A (*Telstar 2*) for May 11–June 30, 1963, prepared by B. Miller.

No. 156, June 25, 1964

Baker-Nunn photography of the *Syncom II* fourth-stage ignition, by R. Citron and L. H. Solomon; and Tracking of Centaur (*AC–2*), by L. H. Solomon.

STAFF CHANGES

Scientists who joined the Observatory staff during the year are Dr. Henry F. Helmken, Dr. Craig Merrihue, and Dr. William G. Elford, physicists; Dr. Richard R. Haefner, supervisor of computations operations; Douglas T. Pitman, chemist; Leendert Aardoom, geodesist; Carlton G. Lehr and Yasushi Nozawa, electronic engineers; and Dr. P. L. Bhatnagar, astrophysicist.

Resignations during the year included those of Dr. Morton J. Davies, Dr. Wolfgang Kalkofen, and Dr. Max Krook, physicists; Dr. Joachim Schubart, celestial mechanician; Richard C. Bruck, chief

of station operations; and Col. Olcott M. Brown (now serving as consultant), station coordinator of Moonwatch.

Consultants at the Observatory during the year were Dr. Pol Swings, Dr. John A. Wood, Sir A. C. B. Lovell, Mr. Thomas C. Marvin, Dr. George Murray, and Dr. Om P. Rustgi.

On June 30, 1964, the Observatory employed 404 persons.

DIVISION OF RADIATION AND ORGANISMS

Prepared by W. H. Klein, *Chief of the Division*

Research of the Division of Radiation and Organisms is directed toward those areas of investigation in which radiation affects or controls, directly and indirectly, the functions of living organisms. Specific areas which have been investigated intensively by the division include the control of regulatory mechanisms by nonionizing radiation such as photomorphogenesis, phototropism, the induction of photosynthetic activity and the interaction of ionizing radiation with synthetic and morphological systems, such as the effects of X-rays and gamma rays at the cellular and subcellular levels. Research has continued on the storage of energy in and synthesis of macromolecules in such diverse systems as higher plants and marine algae. The service activity of the carbon-dating laboratory has been expanded, and the division also conducts basic research in developing and extending dating techniques.

Investigation of the mechanism by which chloramphenicol, an antibiotic protein inhibitor, inhibits light-dependent development of photosynthetic activity of bean leaves has been continued. The chloramphenicol prevents formation of a normal chloroplast structure, the absence of which is correlated with a larger percentage of water-soluble plastid protein. Investigations by serological techniques of differences between water-soluble proteins of plastids from treated and untreated leaves are in progress. The results indicate that there are different proteins in the soluble fractions from the two sources. The plastids from treated and untreated leaves differ in ability to generate antibodies, indicating differences in arrangement of proteins in the two types of plastids.

Although diatoms grown in the dark synthesize photosynthetic pigments, less chlorophyll is produced than in the light. Some evidence indicating a difference in the ratio of chlorophylls to carotenoids in light- and dark-grown cells has been obtained. Changes in the absorption spectrum of diatom cells brought about by heating also occur on treatment with chemicals known to bring about changes in the configuration of protein molecules. Studies on the changes of the absorption spectra of the diatom cells that occur on heating

suggest a different molecular environment for carotenoids and chlorophylls.

In the area of phosphorus metabolism the structure and physiology of ribonucleic acid-polyphosphates in algae have been studied. Extracts have been obtained from synchronous algal cultures, and polymers have been hydrolyzed by various means; the low molecular-weight products have been investigated to ascertain the linkage group which connects the ribonucleic acid to polyphosphates. In December 1963 through February 1964, an extensive Antarctic collecting trip aboard the U.S.S. *Eltanin* was made. Algal and diatom collections were made in the Humboldt current off the coast of Chile and in a great circle arc from Valparaíso to Peter I Island. From these plankton, sample determinations were made on total phosphorus and organic nitrogen. The distribution of phosphorus within certain compounds and relative rates of radioactive phosphate incorporation into various fractions were determined. Concurrently, sea-water samples were obtained at the same sites at which organisms were collected to determine the major nutrients to which the plankton were exposed.

A glycopeptide was isolated, purified, and characterized from the green alga *Chlorella pyrenoidosa*. This glycopeptide contains sialic acid, a sugar derivative which has not previously been reported in any photosynthetic organism. Sialic acid confers antigenic specificity upon such macromolecules as blood-group substances and bacterial cell-wall sheaths.

The continued investigation of intracellular, phytochrome-mediated responses in corn-leaf sections has demonstrated a light catalyzed utilization of carbohydrates more closely associated with the radiant-energy stimulus than any other phytochrome-mediated biochemical response reported heretofore. Increase in utilization occurs well before any growth response is detectable. Total sugar loss is the first change observable, preceding starch disappearance. Specific sugar changes occurring during the first hours immediately following the light pretreatment reveal major changes in both nonreducing and reducing sugars.

Continuation of the studies on the correlation between measured *in vivo* changes in phytochrome pigment concentrations and observed physiological responses induced by red or far-red irradiation show that the logarithmic change in pigment concentration correlates exactly with the physiological dose-response curve for initial light treatments. The time rate of bean hypocotyl hook opening has been measured by time-lapse photography. The rate of hook opening is directly proportional to the intial dose of red light. The onset of opening occurs after about 5 hours and is the same for all exposures.

The fact that the opening rate remains linear for as long as 20 hours suggests that the magnitude of the final opening is directly proportional to the amount of phytochrome produced by the initial red-light exposure. However, any subsequent light treatments after the initial ones show no correlation between the physiological system and the measured *in vivo* pigment changes. Possible explanations for these results are that only a small amount of the phytochrome is active, that there is another form of the pigment as yet undetected, or that the amount of phytochrome required to initiate the physiological response cannot be detected by available instrumentation. At present, our experimental data indicate that current theories are deficient and need revision or modification.

The action spectra for growth and tropic responses in Phycomyces blakesleeanus have been extended into the near ultraviolet. The spectra in this range indicate that either a second pigment system is involved or that bleaching of the photoreceptor occurs.

Experiments measuring the activity of extracts of sporangiophores in the luciferin-luciferase assay system indicated that a 50-percent change of activity occurs within 30 seconds after a blue-light stimulus. There is no correlation between luciferin-luciferase activity and the level of adaptation of sporangiophores. The activity is constant for all levels of adaptation. Comparison between growing and nongrowing samples indicated that all of the luciferin-luciferase activity changes occur in the growing zones. These experiments show that one of the early metabolic systems affected by blue-light stimuli involves high-energy phosphate compounds such as adenosine triphosphate which are active in the luciferin-luciferase assay.

The blue fluorescing unknown which was reported previously to be present in large amounts in light-sensitive stages of sporangiophore development has been isolated in large enough amounts to be identified. This material is a derivative of gallic acid and can be prepared directly from gallic acid in the laboratory. Gallic acid is known to occur at near-saturation concentrations in the sporangiophore, and it is surprising that a material which correlates with the light-sensitivity of sporangiophores is derived from material present in such large amounts.

To date, 80 samples of archeological, geological, and hydrological interest have been analyzed by the carbon-dating laboratory, most of them having been submitted in connection with research at the Smithsonian.

Carbon-14 determinations on the dissolved bicarbonate in ground water have permitted estimates to be made on the flow rates in certain mountain areas in Arizona. Such high-resolution age determination is possible in certain situations owing to the rapid rise in atmospheric

carbon-14 produced by thermonuclear devices. It is assumed that the carbon dioxide in the water as it entered the ground-water system was in isotopic equilibrium with the atmosphere, and that the carbon dioxide the water picked up as it percolated into the ground-water system was from recently decayed organic material. Thus, the recharge water would have a carbon-14 age of less than two years. Measurement of the carbon-14 content of water near the recharge area bears out this assumption. It is further assumed that exchange of carbon dioxide with older carbonate in the system is insignificant. The resultant data for water from a particular locality will be the average travel time of the water from the recharge areas to the sample locality. In the cases studied, water requires less than 10 years to get from the top of the mountain as rain to the main ground-water system at the base of the mountain.

The simultaneous measurement of spectral quality regions of sun and sky radiation as perceived by a horizontal flat receiver is progressing. Technical difficulties encountered in automating the recording system have been largely overcome or corrected by modification and adaptation. We expect to achieve a continuous operation by early fall.

Preliminary experimental data from plant material have been obtained, primarily to test the operation of the growth rooms and greenhouse. These results indicate that, within specified limits, the growing rooms and greenhouse area can be controlled and made uniform with each other in respect to light intensity, temperature, carbon-dioxide content, and day length. The photosynthetic rates of the plant material in the three areas, as measured by dry-weight production, are uniform, indicating that the physical control system operates effectively.

PUBLICATIONS

Klein, William H.; Price, L.; and Mitrakos K. Light stimulated starch degradation in plastids and leaf morphogenesis. Photochemistry and Photobiology, vol. 2, pp. 233–240, 1963.

Mitrakos, K. Chlorophyll metabolism and its relationship to photoperiodism, endogenous daily rhythm and red, far-red reaction system. Photochemistry and Photobiology, vol. 2, pp. 223–231, 1963.

Price, Leonard; Mitrakos, K.; and Klein, W. H. Photomorphogenesis and carbohydrate changes in etiolated leaf tissue. Quart. Rev. Biol., vol. 39, pp. 11–18, 1964.

Sigalove, Joel J., and Long, A. Smithsonian Institution radiocarbon measurements I. Radiocarbon, vol. 6, pp. 182–188, 1964.

OTHER ACTIVITIES

The division was represented during the year at a number of scientific meetings. In attendance at the American Institute of Biological Sciences meeting in August at the University of Massachusetts, Amherst, Mass., were J. L. Edwards, R. H. Gettens, Dr. W. H. Klein,

Dr. R. L. Latterell, Dr. M. M. Margulies, Dr. K. Mitrakos, L. Price, and Dr. W. A. Shropshire. Papers presented at the meetings included "Light-induced Biochemical Changes in Phycomyces Sporangiophores," by Miss Gettens and Dr. Shropshire; "Red, Far-red System and Phytochrome," by Mr. Edwards and Dr. Klein; "Chloroplasts from Chloramphenicol Treated leaves," by Dr. Margulies; and "Phytochrome Mediated Carbohydrate Responses in Etiolated Corn Leaf Sections," by Dr. Mitrakos, Mr. Price, and Dr. Klein. Dr. Klein attended the executive committee sessions of the American Society of Plant Physiologists and was chairman of a session.

J. H. Harrison attended the Intermediate Seminar for Scientific Glass Blowers held in July at the State University of New York, Alfred, N.Y.

Joel J. Sigalove traveled to Tucson, Ariz., in September to collect water samples to determine flow rates of ground water in certain mountain areas of Arizona. In October Dr. Margulies was a participant in a symposium on "Photosynthetic Mechanisms of Green Plants" sponsored by the Photobiology Committees of the National Academy of Science—National Research Council at Warrenton, Va.

Mr. Sigalove and Austin Long attended the Geological Society of America meeting held in New York City in November.

Mr. Goldberg and Mr. Harrison attended a 2-week training course in programing computers given by the Control Data Corporation in Rockville, Md.

In December Dr. D. L. Correll participated in a 3-month Antarctic collecting trip aboard the National Science Foundation vessel, the U.S.S. *Eltanin*. The party sailed from Valparaiso, Chile, on December 17 and spent 2 months collecting in the Antarctic Ocean.

Dr. Shropshire attended the annual meetings of the Biophysical Society in Chicago in February. Dr. Klein spent a week in March in San Juan and Mayaguez, Puerto Rico, consulting with staff scientists of the U.S. Atomic Energy Commission installations. Dr. Correll attended the regional meetings of the American Chemical Society in April at the University of Maryland, College Park. In May Dr. Klein was a visiting lecturer at the University of Texas in Austin. Dr. Correll attended meetings of the American Society of Limnology and Oceanography in Miami, Fla., June 14–20, and presented his paper "Pelagic Phosphorus Metabolism in the Antarctic."

Dr. Margulies presented a lecture at the Research Institute of Advanced Studies in Baltimore on June 10. Dr. Shropshire traveled in June to Cold Spring Harbor, N.Y. to confer with Dr. John Cairns at the biological laboratory.

STAFF CHANGES

Scientists who joined the staff during the year are Austin Long, geochemist in the carbon-14 laboratory, and Dr. Adolf Steiner, visiting plant physiologist from the University of Freiburg, Germany. Dr. Peter A. J. deLint, visiting plant physiologist, returned to Wageningen, Holland. Resignations: Dr. R. L. Latterell, cytogeneticist, and J. Sigalove, geochemist.

On June 30, 1964, the Division staff numbered 32 members.

Respectfully submitted.

Fred L. Whipple, *Director*.

S. Dillon Ripley,
Secretary, Smithsonian Institution.

Report on the National Collection of Fine Arts

Sir: I have the honor to submit the following report on the activities of the National Collection of Fine Arts for the fiscal year ended June 30, 1963:

SMITHSONIAN ART COMMISSION

The 41st annual meeting of the Smithsonian Art Commission was held in Washington on Tuesday, December 3, 1963. Members present were Paul Manship, chairman; Leonard Carmichael, secretary; Gilmore D. Clarke, David E. Finley, Lloyd Goodrich, Walker Hancock, Bartlett H. Hayes, Jr., Henry P. McIlhenny, Paul Mellon, Ogden M. Pleissner, Edgar P. Richardson, Charles H. Sawyer, and Andrew Wyeth. Also present were James C. Bradley, Assistant Secretary; Theodore W. Taylor, Assistant to the Secretary of the Smithsonian Institution; Thomas M. Beggs, Director, National Collection of Fine Arts, and David W. Scott, Assistant Director.

The Commission recommended the appointment of Page Cross to fill the vacancy caused by the resignation of Douglas Orr.

Recommendations were made for the reappointment of Lloyd Goodrich, Bartlett H. Hayes, Jr., and Walker Hancock for the usual 4-year period.

Dr. Leonard Carmichael, who was to retire as Secretary of the Smithsonian Institution on January 31, 1964, was elected Member Emeritus of the Commission.

The following officers were elected for the ensuing year: Paul Manship, chairman; Gilmore D. Clarke, vice chairman; and Leonard Carmichael, secretary (to be succeeded by S. Dillon Ripley upon his assumption of duties as Secretary of the Smithsonian Institution).

The following were elected members of the executive committee for the ensuing year: David E. Finley, chairman; Gilmore D. Clarke; Ogden M. Pleissner; Edgar P. Richardson; with Paul Manship and Leonard Carmichael, *ex officio* (to be succeeded by S. Dillon Ripley upon his assumption of duties as Secretary of the Smithsonian Institution).

Dr. Carmichael reviewed the purpose of the National Collection of Fine Arts for the Commission and indicated the current status of the development on the proposed new gallery in the Old Patent Office

Building. He noted the passage of the fiscal year 1964 appropriation bill providing $5,465,000 for renovation of this building.

The Commission recommended acceptance of the following for the National Collection of Fine Arts:

Oil, *Group Portrait of Anna Maria Mabie, John Henry Mabie, and George Winfield Mabie*, by Undetermined Artist. Offered by Mr. and Mrs. William A. Sturm, Bladensburg, Md.

Fifty-eight pen-and-ink drawings by E. C. Peixotto (1869–1940). Offered by Fortunato Porotto, Washington, D.C.

Two miniatures, watercolor on ivory, *Emilia Field Brewer*, possibly by John Henry Brown (1818–1891), and *Portrait of a Child*, by Undetermined Artist. Offered by Mrs. David Karrick, Washington, D.C.

A miniature, watercolor on ivory, *Unknown Gentleman*, by Undetermined Artist. Offered by Mrs. C. H. Roper, Austin, Tex.

The Commission recommended that the following be added to the Study Collection:

Pastel, *The New Moon*, by George Randolph Barse, Jr. (1861–). Offered by Eugene W. Bolling, Upper Montclair, N.J.

Miniature, oil on porcelain, *Two Girls in a Garden*, by Undetermined Artist. Offered by Mrs. David Karrick, Washington, D. C.

The Commission recommended that the following be held for submission to the National Portrait Gallery Commission:

Two sculptures, bronze, *William Howard Taft* (1857–1930), and terracotta, *Cordell Hull* (1871–1955), by Bryant Baker (1881–). Offered by the sculptor, New York City.

Oil, *General John J. Pershing* (1860–1948), by Leopold Seyffert (1887–1956). Offered by Mr. and Mrs. Dudley Cooper, Norfolk, Va.

The Commission recommended that the following be added to the Lending Collection:

Oil, *3:00 a.m.*, by Adelaide Morris Gardner. Offered by Mrs. Fred Gardner, Sarasota, Fla.

THE CATHERINE WALDEN MYER FUND

The following miniatures, watercolor on ivory, were acquired from the fund established through the bequest of Catherine Walden Myer:

No. 150. *Barnabus Bates*, attributed to Thomas Sully (1783–1872). Acquired from Mrs. Eva W. Chadbourne, Washington, D.C.

No. 151. *Betsy Goodrich*, by Sarah Goodridge (1788–1858).

No. 152. *R. M. Copeland*, by Thomas Edwards (ac. 1822–1856, Boston).

No. 153. *Child*, attributed to Edward Greene Malbone (1777–1802).

No. 154. *James Morris*, by Henry Colton Shumway (1807–1884).

No. 155. *Mrs. James Morris*, by Henry Colton Shumway (1807–1884).

No. 156. *Lewis Gaylord Clark*, attributed to Charles Loring Elliot (1842–1868).

No. 157. *Gentleman*, by Undetermined Artist (resembling the style of Copley).

No. 158. *Lady*, by Bernard Lens (1682–1740).

Nos. 151–158 acquired from Edwin C. Buxbaum, Wilmington, Del.

STUDY COLLECTION

The Director and curatorial staff accepted the following for the Study Collection:

Four silhouettes and a miniature, by Undetermined Artist. Offered by the Misses Gatchell, Washington, D.C.

One miniature, by Undetermined Artist, and other related material. Offered by Miss Mary Schaff, Washington, D.C.

Watercolor, *Williamburg Post Office*, by Dwight Williams. Offered by Felix Stapleton, Washington, D.C.

WORKS OF ART LENT AND RETURNED, PERMANENT COLLECTION

Institutions	*Loans*	*Loans returned*
American Federation of Arts	2	--
Bowdoin College	1	--
Bureau of the Budget	27	--
General Services Administration	3	1
Indian Claims Commission	--	1
Interior, Department of the	1	--
International Business Machines Corporation	3	3
Interstate Commerce Commission	3	--
Joslyn Art Museum	--	1
Justice, Department of	2	--
Museum of Fine Arts, Boston	1	1
Portland Museum, Maine	1	1
State, Department of	1	--
University of Arizona Art Gallery	1	1
U.S. Antarctic Projects	1	--
U.S. District Court for the District of Columbia	2	--
U.S. District Court, Richmond, Va	12	--
U.S. Information Agency	1	1
U.S. Senate	1	--
Washington County Museum of Fine Arts	14	14
The White House	3	2
The White House (Plans for Progress Office)	10	--
The White House (Office of Special Representative for Trade Negotiations)	9	--
Whitney Museum of American Art	1	1
	100	27

WORKS OF ART LENT AND RETURNED, LENDING COLLECTION

Institutions	*Loans*	*Loans returned*
Barney Neighborhood House	12	2
Bureau of the Budget	16	--
Foxcroft School	1	1
Health, Education, and Welfare, Department of	2	--
Howard University	19	16
Mount Pleasant Library	2	--
President's Advisory Committee on Science	6	--
Tuskegee Institute	--	1
U.S. District Court for the District of Columbia	5	--
The White House	2	2
The White House (Office of Special Representative for Trade Negotiations)	8	--
	73	22

ALICE PIKE BARNEY MEMORIAL FUND

Additions to the principal during the year amounting to $2,088.06 increased the total invested sums in the Alice Pike Barney Memorial Fund to $47,512.55.

THE HENRY WARD RANGER FUND

According to a provision of the Henry Ward Ranger bequest, that paintings purchased by the Council of the National Academy of Design from the fund provided by the bequest and assigned to American art institutions may be claimed during the 5-year period beginning 10 years after the death of the artist represented, the following paintings were recalled for action of the Smithsonian Art Commission at its meeting December 3, 1963:

No. 140. *Tide Water Creek, Oregon* (watercolor), by Theodore Kautzky (1896–1953), was accepted to become a permanent accession.

No. 179. *The Eviction* (pastel), by Everett Shinn (1876–1953), was accepted to become a permanent accession.

The following paintings, purchased by the Council of the National Academy of Design since the last report, have been assigned as follows:

Title and artist	*Assignment*
278. *Milestone* (oil), by Philip B. White (1935–).	Assignment pending.
279. *Interior with Figure* (oil), by Sarah Blakeslee (1912–).	Hackley Art Gallery, Muskegon, Mich.
280. *The Beach* (oil), by Hughie Lee-Smith, (1915–).	Assignment pending.
281. *From my Window* (oil), by Jacques Hnizdovsky (1915–).	University of Delaware, Newark, Del.
282. *Portrait of Susan B. Stewart* (oil), by Walter Stuempfig (1914–).	Birmingham Museum of Art, Birmingham, Ala.
283. *Connemara* (oil), by Colleen Browning (1925–).	Assignment pending.
284. *The New Tent* (oil), by Sperry Andrews (1917–).	Pomona College, Claremont, Calif.
285. *The Wait* (watercolor), by Doris White (1924–).	Assignment pending.
286. *Reunion* (oil), by Richard Wynn (1928–).	Assignment pending.
287. *The High City* (watercolor), by Betty Bowes (1911–).	University of Southern California, Los Angeles, Calif.
288. *Landscape* (watercolor), by Douglas Gorsline (1913–).	Rollins College, Winter Park, Fla.
289. *Mountain Glen* (watercolor), by Henry C. Pitz (1895–).	Fine Arts Gallery, University of Colorado, Boulder, Colo.
290. *Expressway Site* (watercolor), by Charles Taylor (1910–).	Assignment pending.
291. *Roof Tops, Ste. Agnes* (watercolor), by Stuart Garrett (1922–).	Assignment pending.
292. *Ludlow Snow* (watercolor), by David M. Checkley (1917–).	The University Guild, Northwestern University, Evanston, Ill.
293. *Embankment, III* (watercolor), by Glenn R. Bradshaw (1922–).	Fine Arts Gallery of San Diego, San Diego, Calif.
294. *North of Truro* (watercolor), by Saraga P. Saffer (1927–).	Museum of New Mexico, Santa Fe, N. Mex.
295. *Studio Interior* (watercolor), by Wick Knaus (1928–).	Assignment pending.
296. *Beach at Quoque* (watercolor), by Joseph W. Arcier (1909–).	Sioux City Art Center, Sioux City, Iowa.
297. *Gathering Storm* (watercolor), by Forrest Orr (1895–).	Assignment pending.
298. *Viaduct* (watercolor), by Fred B. Marshall (1904–)	Assignment pending.

SMITHSONIAN TRAVELING EXHIBITION SERVICE

Mrs. Dorothy T. Van Arsdale was appointed Acting Chief to replace Mrs. Annemarie Pope, who was named Special Assistant to the Secretary for Traveling Exhibition Study in May of this year.

In addition to 99 exhibits held over from previous years as indicated below, 37 new shows were introduced. The total of 139 shows was circulated to 297 museums in the United States. Two exhibitions were delivered to the U.S. Information Service for circulation abroad.

EXHIBITS CONTINUED FROM PRIOR YEARS

1956–57: Japan II by Werner Bischof.

1957–58: The American City in the 19th Century; Theatrical Posters of the Gay Nineties; Japanese Dolls.

1958–59: Advertising in 19th Century America; Religious Subjects in Modern Graphic Arts; Our Town; Shaker Craftsmanship.

1959–60: American Prints Today; Brazilian Printmakers; Arts and Cultural Centers; Photographs by Robert Capa II; Prints and Drawings by Jacques Villon; Portraits of Greatness by Yousuf Karsh; Paintings by Young Africans; Japan I.

1960–61: The Technique of Fresco Painting; The America of Currier and Ives; Drawings by Sculptors; Eskimo Graphic Art; American Art Nouveau Posters; Japan by Werner Bischof; The Spirit of the Japanese Print; Americans—A view from the East; Contemporary Swedish Architecture; Mies van der Rohe; Irish Architecture of the Georgian Period; Brasilia—A New Capital; Design in Germany Today; Designed for Silver; American Textiles; The Seasons, color photographs by Eliot Porter; The World of Werner Bischof; The Image of Physics; Charles Darwin: The Evolution of an Evolutionist; The Beginning of Flight; The Magnificent Enterprise—Education Opens the Door; The New Theatre in Germany; Tropical Africa I; Tropical Africa II; Symphony in Color; Paintings and Pastels by Children of Tokyo; Children's Art from Italy; Hawaiian Children's Art; Designs by Children of Ceylon.

1961–62: Tutankhamun's Treasures: Fourteen Americans in France; George Catlin, Paintings and Prints; Physics and Painting; UNESCO Watercolor Reproductions; Belgian Drawings; The Lithographs of Childe Hassam; Contemporary Italian Drawings; John Baptist Jackson; Contemporary Swedish Prints; Japanese Posters; The Face of Viet Nam; Architectural Photography (New Editions); Le Corbusier—Chapel at Ronchamp; The Family, The Neighborhood, the City; One Hundred Books from the Grabhorn Press; Wisconsin Designer-Craftsmen; Caribbean Journey; The Swedish Film; The Story of a Winery; This is the American Earth; The Hidden World of Crystals; Hummingbirds; Brazilian Children's Art; Children Look at UNESCO; My Friends.

1962–63: The Daniells in India; Eskimo Carvings; Holland: The New Generation; John Sloan; Contemporary Japanese Sumi Paintings; American Prints Today, 1962; Contemporary American Drawings; Work by Ernst Barlach; Old Master Drawings from Chatsworth; English Watercolors and Drawings; Eskimo Graphic Art II; Pakistan Stone Rubbings; Contemporary Canadian Architecture; Twelve Churches; Pre-Hispanic Mexico;

766–746—65——14

Today's American Wall-Coverings; Craftmen of the City; The Tradition of French Fabrics; A Child's World of Nature; West German Students' Art; Historic Annapolis; The Old Navy, 1776–1860.

EXHIBITIONS INITIATED IN 1964

Archeology

7000 Years of Iranian Art	Iranian Government; Archaeological Museum in Tehran; Madam Foroughi.

Paintings and Sculpture

The Bird That Never Was	Musée National d'Art Moderne in Paris; Artist.
Indian Miniatures	India Library, London, Mrs. Mildred Archer; P & O Lines.
Religious Themes by Old Masters	Inter Nationes, Bonn; German Embassy.
Turner Watercolors	British Museum, Mr. E. Croft-Murray.

Drawings and Prints

Fifty Years of American Prints	Pennell Fund Collection, Library of Congress, Washington, D.C.
Antonio Frasconi 1952–1963	The Artist.
Prints by Mary Cassatt	The National Gallery of Art, Washington, D.C.
Graphics '63	Mr. Richard Freeman, University of Kentucky.
Treasures from the Plantin-Moretus Museum	Plantin-Moretus Museum, Antwerp.
Eighteenth Century Venetian Drawings	Correr Museum, Venice, Dr. Terisio Pignatti.

Design and Crafts

Albers: Interaction of Color	Yale University Press.
American Costumes	Index of American Design, National Gallery of Art, Washington, D.C.
Eugene Berman—New Stage Designs	Artist; M. Knoedler & Company, New York City.
Craftsmen of the Eastern States	Museum of Contemporary Crafts, New York City, Mr. Paul Smith.
Eskimo Carvings	Eskimo Art, Inc., Ann Arbor, Mich., Mr. Eugene Powell.
Finnish Rugs and Tapestries by Oili Maki	Artist.
Masters of Ballet Design	Spreckels Collection, California Palace of the Legion of Honor, San Francisco, Calif.
Swedish Design Today	Svensk Form-Design Center, Stockholm, Ake Huldt, Managing Director.

Swedish Folk Art	Nordiska Museset, Stockholm; Dr. Eskerod, Swedish Embassy.
Swiss Posters	Pro Helvetia, Zurich; Embassy of Switzerland.

Architecture

Alvar Aalto	Traveling Exhibition Service, Mr. E. Kidder-Smith, Photographer.
Contemporary American Landscape Architecture	Hubbard Educational Trust; American Society of Landscape Architects.
Recent American Synagogue Architecture	Mr. Richard Meier, Architect; Jewish Museum in New York.
Eero Saarinen	Public Relations Department, TWA, New York; Ezra Stoller, Photographer.
Historic Annapolis	Historic Annapolis, Inc.

History

The American Flag	Library of Congress, Washington, D.C.
Hearts and Flowers	Hallmark Historical Collection, Hallmark Cards, Inc., Kansas City, Mo.
World Fairs	Prints and Photographs Division, Library of Congress, Washington, D.C.

Children's Art

American Kindergarten Art	National Kindergarten Association.
Paintings by Young Balinese	Collection of Mrs. Gordon Wiles, Encino, Calif.
Washington—My City	District Art Department, Washington, D.C.

Natural History and Science

Birds of Asia	Loke Wan Thos, Chinese Photographer.

Photography

Africa, Antarctica, The Amazon	IBM Gallery, New York City.
African Folkways of Angola and Mozambique	National Geographic Society; Museum of Primitive Art, New York City.
The Eloquent Light—Ansel Adams	Mrs. Nancy Newhall, George Eastman House, Rochester, N.Y.
The Nile	Eliot Elisofon, Photographer.

LIBRARY

During the year the library accessioned 784 publications, 416 of which were obtained through exchange or gift. In all, 178 books and 36 subscriptions to periodicals were purchased.

The slide collection was greatly augmented. A checklist of slides was instituted; 2,537 slides were accessioned. The Carnegie Corporation aided in the purchase of the *Carnegie Survey*, *Arts of the United States.*

STAFF ACTIVITIES

Thomas M. Beggs, Director of the National Collection of Fine Arts for 17 years, was appointed Special Assistant to the Secretary for Fine Arts. David W. Scott was appointed Assistant Director, and subsequently, Acting Director.

During the past year the following were added to the staff: Val Lewton, museum technician; Robin Bolton-Smith, research asistant; Judith Chance, clerk-typist.

The office handled approximately 1,800 personal inquiries, in addition to about 22,000 requests for information by mail and telephone; 437 works of art were examined by the curatorial staff and the director.

The reserve, permanent, and the lending collections were installed in a new screen storage area, and the foyer gallery was refurbished.

Physical inventory of paintings, sculpture, prints, and miniatures in the collection has been completed and an inventory of the decorative arts collection was begun by staff members. Two preliminary catalog listings, one of paintings, drawings, and sculpture, the other of graphic arts, were completed by Robin Bolton-Smith, Donald McClelland, and David W. Scott. A survey of W.P.A. paintings at the Department of Labor was carried on by Val Lewton.

Thomas M. Beggs wrote the catalog introductions to the Washington County Museum exhibition *Old Masters* and the Department of State exhibition *American Indian and Eskimo Arts and Crafts.* An article on Ralph Earl was published in *Antiques Journal* by Rowland Lyon. Staff members served as jurors for local art exhibitions and lectured on the collection.

A survey concerning the development of the collection was completed by John Kerr. Special services with reference to cataloging were performed by Keyes Porter. Delight Hall prepared a text on the Alice Pike Barney Memorial Collection and began an inventory of the paintings. The inventory was completed by Jean Lawton. A survey of art in Government buildings was undertaken by Miss Hall, but was interrupted by the unfortunate accident which caused her death.

Henri G. Courtais restored and repaired the following paintings:

John Gellatly, by Irving R. Wiles (1861–1948); *Lord Mulgrave*, by Thomas Gainsborough (1727–1788); *Mary Hopkinson*, by Benjamin West (1738–1820); *Edinburgh—A Painting of Sunlight and Air*, by Joseph M. W. Turner (1775–1851); *Water Carriers, Venice*, by Frank Duveneck (1848–1919); *Joseph Head*, by Gilbert Stuart (1755–1828); *Madonna and Child with St. John and an Angel*,

by Sebastiano Mainardi (1466–1513) ; *At Nature's Mirror*, by Ralph Albert Blakelock (1847–1919) ; *Moonrise*, by Ralph Albert Blakelock (1847–1919) ; *Man with a Large Hat*, by Rembrandt van Rijn (1606–1669) ; *The Prince of Wales*, by Sir John Watson Gordon (1790–1864) ; *The Great Western*, by William Marsh (fl. 1844–1858) ; *Pomona*, by Childe Hassam (1859–1935) ; *Young Girl in a Green Bonnet*, by Mary Cassatt (1845–1926).

Harold F. Cross restored and repaired the following paintings:

Natalie with a Violin, by Alice Pike Barney (1857–1931) ; *Sundown*, by George Inness (1825–1894) ; *The Brass Kettle*, by Alice Pike Barney (1857–1931) ; *Hippolyte Dreyfus*, by Alice Pike Barney (1857–1931) ; *Lord Abercorn*, by Sir Thomas Lawrence (1769–1830) ; *The Mystic Marriage of St. Catherine of Alexandria*, by Giacomo Francia (1486–1557) ; *View in Rome with the Church of Ara Coeli*, by School of Canaletto ; *L'Automne*, by Pierre Puvis de Chavannes (1824–1898) ; *Feldama*, by George Fuller (1822–1884) ; *Westward the Course of Empire Takes its Way*, by Emanuel Leutze (1816–1868) ; *Gentleman*, by Sir Godfrey Kneller (1646–1723) ; *The Doctor's Visit*, by Jan Steen (1626–1679) ; *Dutch Landscape with Figures*, by Jacobus van Strij (1756–1815).

Repairs and regilding were done to 88 frames for paintings, prints, and watercolors by Val Lewton, Linwood Lucas, and Istvan Pfeiffer.

SPECIAL EXHIBITIONS AND EVENTS

July 3–August 1, 1963. Tenth Interservice Photography Contest, sponsored by the Department of Defense.

August 10–September 2, 1963. Sixteenth International Congress of Zoology, sponsored by the United States National Museum.

September 8–29, 1963. Pakistan Stone Rubbings, circulated by the Smithsonian Institution Traveling Exhibition, together with Pakistan textiles and jewelry lent by Mrs. E. J. W. Bunting, and miscellaneous objects from the Division of Ethnology, USNM. A catalogue was privately printed.

September 8–October 10, 1963. Ninth International Exhibition of Ceramic Art, sponsored by the Kiln Club of Washington, D.C. An illustrated catalogue was privately printed.

October 5–24, 1963. Seventieth Annual Exhibition of the Society of Washington Artists. A catalogue was privately printed.

November 3–24, 1963. American Artists Professional League under the auspices of the New Jersey Chapter. Memorial to Frederick Ballard Williams. A catalogue and brochure were privately printed.

December 8–January 2, 1964. Twenty-sixth Anniversary of the Metropolitan Art Exhibition, sponsored by the American Art League. A brochure was printed privately.

December 8, 1963–January 2, 1964. Hearts and Flowers, a history of the greeting card from the 18th century to 1910, circulated by the Smithsonian Institution Traveling Exhibition Service, from Hallmark Historical Collection, Kansas City, Mo.

January 11–February 2, 1964. Ninth Annual Painting of the Year Exhibition, sponsored by the Mead Corporation. A special catalogue was privately printed.

January 12–30, 1964. African Folkways in Angola and Mozambique, photographs by Volkmar Wentzel, under the auspices of the National Geographic Society and the Museum of Primitive Art.

January 20, 1964. Images of Hawaii—from Captain Cook to Contemporary Crossroads—a lecture on the development of Hawaiian art by Ben Norris, profes-

sor of art at the University of Hawaii, sponsored by the Hawaii State Society of Washington, D.C.

February 8–March 1, 1964. Twenty-fifth National Exhibition of the Society of Washington Printmakers. A catalogue was privately printed.

February 8–March 1, 1964. Prints by Antonio Frasconi, 1952–1963, circulated by the Smithsonian Institution Traveling Exhibition Service. A special brochure was privately printed.

February 10–March 8, 1964. An oil painting, "The Range Burial," by Harry Jackson, together with related sculptures and studies, sponsored by the Honorable Milward Lee Simpson, Senator from Wyoming, the Wyoming State Society of Washington, D.C., and the Coe Foundation. An illustrated catalogue was privately printed.

March 7–29, 1964. Craftsmen of the Eastern States, an exhibit of textiles, ceramics, jewelry, metalwork, and furniture, circulated by the Smithsonian Institution Traveling Exhibition Service. A special catalogue was privately printed.

April 5–23, 1964. The twenty-second Biennial Art Exhibition, sponsored by the National League of American Pen Women. A catalogue was privately printed.

April 4–26, 1964. Graphics '63, sponsored by the University of Kentucky and circulated by the Smithsonian Institution Traveling Exhibition Service. A catalogue was privately printed.

May 3–21, 1964. Sixty-seventh Annual National Exhibition of the Washington Watercolor Association.

May 3–21, 1964. Thirty-first Annual Exhibition of the Miniature Painters, Sculptors, and Gravers Society of Washington, D.C.. A special catalogue was privately printed.

May 2–24, 1964. The Nile, photographs by Eliot Elisofon, circulated by the Smithsonian Institution Traveling Exhibition Service. A special book was printed.

May 11–June 14, 1964. Sculpture and Drawings by Juan de Avalos, sponsored by the Ambassador of Spain. A catalogue was privately printed.

June 27–July 19, 1964. Tuscany in the 19th Century, an exhibition of paintings, sponsored by the American Federation of Art and the Ambassador of Italy.

Respectfully submitted.

David W. Scott, *Acting Director.*

S. Dillon Ripley.
Secretary, Smithsonian Institution.

Report on the Freer Gallery of Art

SIR: I have the honor to submit the 44th annual report on the Freer Gallery of Art, for the year ended June 30, 1964.

THE COLLECTIONS

Twenty-two objects were added to the collections by purchase as follows:

METALWORK

63.15. Persian, Achaemenid, 6th/5th century B.C. Wild goat, rearing, with front legs bent double. Gold, hollow; a band of fine gold wire over center of body. Originally one of two handles of an amphora-shaped vase. Cf. 64.6. Three small holes. Height: 0.196; weight: 5 oz. (Illustrated.)

64.3. Persian, Sasanian, 6th/7th century A.D. Vase, silver, partially gilded; triangular notched design repeated three times; tri-lobed leaf molding around neck. Height: 0.175; diameter (at rim): 0.057; weight: 1 lb. 6½ oz.

64.6. Persian, Achaemenid, 6th/5th century B.C. Wild goat, rearing, with front legs bent double, standing on a tube-like support with chevron pattern and a central rib in relief. Gold, hollow; a band of fine gold wire over center of body. Originally one of two handles of an amphora-shaped vase. Cf. 63.15. Cracks in front of neck and ears. Length: 0.226; weight: 4½ oz. (Illustrated.)

PAINTING

64.2. Chinese, Ming, by Liu Chüeh (1410–72). Landscape, with bamboo grove. Five inscriptions and 10 seals on the painting; 1 seal on the mounting preceding the painting; colophon with 1 seal following the painting. Label on outside mount. Height: 0.336; width: 0.578. (Illustrated.)

64.5. Chinese, Ch'ing, Yang-chou school, by Lo P'ing (1733–99). Album of 12 leaves: landscapes and figures; dated 1774. Painted in ink and colors on paper. Title on outside mount; artist's inscription and seal on each leaf; collector's inscription and two seals on mounting beside last leaf. Height: 0.241; width: 0.305.

63.4. Indian, Mughal, ca. 1588 (996 H.), attributed to 'Abdl al-Ṣamad Shīrīn Qalam. Leaf from the Jahāngīr album: Verso: Jamshīd writing on a rock, retainers in landscape; border of gold flowers and colored birds. Recto: calligraphy (*nasta'līq* by Mīr 'Alī); marginal design with small human figures in gold landscape. Small areas of pigments chipped off. Height: 0.420; width: 0.265.

63.2. Japanese, Ashikaga, Muromachi Suiboku school, by Oguri Sōritsu (16th century). Willows and birds; *sumi* on paper. Kakemono: height: 1.105; width: 0.520.

63.3. Japanese, Edo, Individualist school, by Mori Sosen (1747–1821). Monkeys and waterfall; *sumi* and slight color on paper. Kakemono: height: 0.885; width: 0.310.

63.5. Japanese, Ashikaga, early 15th century, Muromachi Suiboku school, attributed to Shūbun. Landscape; ink on paper. Kakemono: height: 0.905; width: 0.350.

63.6. Japanese, Heian period, 12th century, Buddhist school. The Bodhisattva Fugen. Ink, color, gold and silver on silk. Kakemono height: 1.556; width: 0.831. (Illustrated.)

63.11. Japanese, Edo, 19th century, Individualist school, by Shibata Zeshin (1807–91). Carp. Lacquer on paper. Height: 0.346; width: 0.472.

63.12–13. Japanese, Momoyama period, Kanō school, by Kanō Eitoku (1543–90). A pair of six-fold screens depicting "The Four Accomplishments." Ink on paper. Each screen: height: 1.540; width: 3.540.

63.14. Japanese, Kamakura, Buddhist school. The Bodhisattva Fugen and attendants. Ink, color and gold on silk. Kakemono: height: 1.404; width: 0.730.

POTTERY

63.16. Chinese, Sung, *ting* ware. Shallow bowl with wide, flaring rim bound with copper; small foot. Clay: fine off-white stoneware. Glaze: transparent, slightly bubbly, some "teardrops" on outside. Decoration: two ducks swimming among water plants incised in the paste under the glaze. Height: 0.048; diameter: 0.210.

63.8. Japanese, Edo period, *kakiemon* ware, early 18th century. Deep bowl, octagonal in section, with slightly flaring rim and upright lip. Clay: white porcelain. Glaze: transparent. Decoration: flowers, tree trunks, rocks, and scrolling vines in underglaze blue and overglaze enamel colors; brown rim; single circle in underglaze blue on base. Height: 0.102; diameter: 0.212.

63.9. Japanese, Edo period, *nabeshima ware*. Dish on high foot. Footrim repaired. Clay: fine white porcelain. Glaze: transparent. Decoration: in underglaze blue and overglaze enamel colors; outside, flowers on cavetto and typical "comb pattern on foot"; inside auspicious objects and "kotobuki" reserved in white. Height: 0.058; diameter: 0.203.

63.10. Japanese, Momoyama period, *oribe* ware. Small dish with flattened, foliate rim. Clay: buff stoneware with areas of iron red near the glaze. Glaze: deep green with uneven flow. Decoration: incised, floral motifs and grasses in cavetto; a donkey carrying a grain sack in center. Height: 0.036; diameter: 0.115.

64.1. Japanese, Edo period, 17th century, Ninsei. Rectangular vase with rounded profile, short neck and small out-turning lip. Signature incised on rough unglazed base. Clay: gray stoneware, fired reddish buff. Glaze: uneven reddish brown with black areas. Height: 0.248; width: 0.273 (maximum). (Illustrated.)

64.4. Japanese, Momoyama, *shino-oribe* ware. Bottle, gourd-shaped. Clay: rough stoneware. Glaze: transparent. Decoration: grapes and trellis design. Height: 0.215; diameter : 0.105.

64.7. Japanese, Edo, *nabeshima* ware. Plate, footed. Clay: porcelain. Glaze: partial celadon. Decoration: design in underglaze blue and incised iron. Height : 0.057; diameter : 0.203.

63.7. Turkish, Ottoman period, mid-16th century, *isnik* ware. Plate with a design of zinnias, pomegranates, and hyacinths in light blue, purple, and white on dark blue ground, on the inside; and of two tulips alternating with a zinnia in light and dark blue on white ground on outside wall. Small area along the upper right edge lost and replaced by painted plaster, nicks along edge; two holes in ring-foot for suspension. Height: 0.058: diameter: 0.312.

REPAIRS TO THE COLLECTION

Twenty-four Chinese and Japanese paintings and screens were restored, repaired, or remounted by T. Sugiura, Oriental picture mounter. F. A. Haentschke, illustrator, remounted 34 Persian paintings. Repairs and regilding of six frames for American paintings were done outside the Gallery.

CHANGES IN EXHIBITIONS

Changes in exhibitions amounted to 373, which were as follows:

American art:	
Paintings	11
Chinese art:	
Bronzes	4
Christian art:	
Manuscripts	20
Stone sculpture	1
Indian art:	
Paintings	28
Japanese art:	
Paintings	79
Pottery	27
Lacquer	12
Wood	8
Near Eastern art:	
Metalwork	44
Manuscripts	32
Paintings	79
Pottery	33

LIBRARY

The library has been coming into full use with the recent introduction of courses in Oriental Art in the local colleges and universities. The graduate and undergraduate students, many of whom have used our collection for research, as well as the three students on fellowships studying at the Gallery this past year, have given an impetus to the "diffusion of knowledge."

During the year, 472 items (books, pamphlets, periodical parts) were acquired by the library; 258 of these were by purchase and 214 by exchange and gift. Nineteen microfilms augmented the collection, and the study file increased by 1,069 photographs.

The year's cataloging projects included a total of 900 entries; 596 analytics were made and 199 new titles of books, pamphlets, and microfilms were cataloged. Additions to the sets of books numbered 115, and 3,151 cards were added to the card catalog. Only 11 percent of these were available as printed cards; nearly 90 percent of the cataloging is original work.

Since many instructors at the university Oriental Art courses depend on the library for supplementary material and visual aids, the importance of the slide collection has markedly increased. The library acquired 1,412 new slides, and 2,778 were bound, labeled, classified, or repaired. Slide loans totaled 2,962, of which 487, or 17.5 percent, were for the use of the Gallery staff in their lectures.

There were 434 requests for bibliographic information by telephone and letter. Visitors were frequent: 686 scholars and students who were not members of the Freer staff used the library resources, 5 saw and studied the Washington Manuscripts, and 6 came to see the library equipment and facilities.

After years of searching, two copies of *Shih-chu-chai shu-hua p'u* (*Painting manual from the Ten Bamboo Studio*) were acquired. The larger copy is undated, and has 181 colored illustrations on 45 canon folds, while the second copy has the illustrated text in eight *pên*, published in Shanghai and dated 1879.

Another rare and valuable book, acquired for the documentation of Moronobu's works, is *Byobu kakemono edzukushi* (*Designs for screens and kakemono*), Tokyo, 1701 (first edition published in 1682). This work clearly establishes that Moronobu was familiar with, and followed, other techniques and schools of art besides Ukiyoe.

The following gifts deserve special mention because of their outstanding quality. *Kokuhō henshū-iin* (*National treasures of Japan*), Tokyo, Mainichi Shimbun-sha, 1963—, is a folio set eventually to be complete in six volumes; it is made available to us through the Weedon gift. Another set, *Nikuhitsu Ukiyoe* (*Ukiyoe painting*), Tokyo, Kodansha, 1962–63, two folio volumes, is the gift of Mr. and Mrs. Felix Juda. The staff continues to be generous with their writings and the literature sent to them.

Holdings of Whistler correspondence, 630 leaves in all, were laminated by the Archival Restoration Associates, Inc.

Mrs. Bertha M. Usilton, librarian since 1944, retired on June 30; Mrs. Constance B. Olsen will take charge of the library with the beginning of the new fiscal year.

PUBLICATIONS

Two publications were issued by the Gallery as follows:

Ars Orientalis, Vol. V. 19 articles in English, French, or German, 18 book reviews, 1 bibliography, 2 notes, 3 memorials. 354 pp., 206 plates, text illustrations. (Smithsonian Institution Publication 4540.)

Oriental Studies, No. 6: Armenian Manuscripts in the Freer Gallery of Art, by Sirarpie Der Nersessian, 145 pp., 108 plates. (Smithsonian Institution Publication 4516.)

Publications of staff members were as follows:

CAHILL, JAMES F. Yüan Chiang and his school. Part I. *Ars Orientalis*, vol. 5 (1963), pp. 259–272, 20 pls.

———. Review of "The birth of Landscape Painting in China," by Michael Sullivan. *Burlington Magazine*, vol. 105 (Oct. 1963), p. 452.

———. Translation of "Concerning the I-p'in Style of Painting, Part III," by S. Shimada. *Oriental Art*, n.s. vol. 10 (1964), pp. 19–26, illus.

ETTINGHAUSEN, RICHARD. Iran under Islam. *7000 Years of Iranian Art, circulated by the Smithsonian Institution . . . 1964–65* (1964), pp. 33–46.

———. Art of the Islamic period, bibliography. *7000 Years of Iranian Art, culated by the Smithsonian Institution . . . 1964–65* (1964), pp. 50–51.

———. Chinese representations of Central Asian Turks. *Beiträge zur Kunstgeschichte Asiens; in memoriam Ernst Diez.* Istanbul (1963), pp. 208–222, 16 figs.

———. Historical subjects, The East: Islam. *Encyclopedia of World Art*, vol. VII, cols. 495–497.

———. Masterpieces of Iranian rugs and textiles. [An exhibition at the Textile Museum, Washington, D.C., June 9–September 12, 1964.] 12 pp., 9 illus. on 7 pls.

———. New pictorial evidence of Catholic missionary activity in Mughal India (early XVIIth century). *Perennites . . . P. Thomas Michels . . . zum 70. Geburtstag.* Münster, Verlag Aschendorff (1963), pp. 385–396, 11 pls.

———. Oreeiceria (Goldsmithing); L'Islam. *Enciclopedia Universale dell 'Arte*, vol. 10, cols. 141–142.

———. Pre-Mughal painting in India. *Trudy dvadstat' pyatogo mezhdunarothnogo kongressa vostokovedov, Moskva 1960.* (Proceedings of the 25th International Congress of Orientalists, Moscow, 1960), vol. 4, section 14, pp. 191–192.

———. Some Deccani miniatures in the United States. *Marg*, vol. 16 (March 1963), pp. 14–16, 32–33, 5 illus. (Published as two articles under titles "Bijapur" and "Portfolio [Deccani painting]").

———. Yemenite Bible manuscripts of the XVth century. Jerusalem, Israel exploration society, 1963. *Eretz-Israel*, vol. 7, L. A. Mayer memorial volume, pp. 32–39, 13 pls.

———. Youssef Sida: paintings, drawings, ceramics. An Introduction. [An exhibition at Middle East House, March 17–April 12, 1964, Washington, D.C.] 5 pp.

———. Review of "Introduction à l'histoire de l'Orient Musulman," by Jean Sauvaget. *Der Islam*, bd. 39 (Feb. 1964).

———. Review of "Natural History Drawings in the Indian Office Library," by Mildred Archer. *Journal of Asian Studies*, vol. 22 (Feb. 1963), pp. 250–252.

GETTENS, R. J. Conservators in Russia. *Museum News*, vol. 42 (May 1964), pp. 11–17, 13 illus.

———. Review of "Archaeology and the Microscope; the Scientific Examination of Archaeological Evidence," by Leo Biek. *Science*, vol. 143 (June 3, 1963), p. 36.

POPE, JOHN A. Archibald Gibson Wenley; an appreciation. *Ars Orientalis*, vol. 5 (1963), pp. 1–5, port.

———. Stockholm: The Museum of Far Eastern Antiquities. *Apollo*, vol. 78 (July 1963), pp. 29–33, 8 illus.

———. Review of "Chinese Trade Porcelain," by Michel Beurdeley. *Journal of the American Oriental Society*, vol. 82 (Oct.–Dec. 1962), pp. 601–605.

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———. Review of "Archaeology in China," by William Watson. *Ars Orientalis*, vol. 5 (1963), p. 306.

———. Review of "Chinese Jade Throughout the Ages; a Review of Its Characteristics, Decoration, Folklore and Symbolism," by Stanley Charles Nott. *Burlington Magazine*, vol. 105 (Oct. 1963), pp. 452–453.

USILTON, BERTHA M. Bibliography and writings of James Marshall Plumer. *Ars Orientalis*, vol. 5 (1963), pp. 331–337.

———. The museum library. *Museum News*, vol. 42 (Oct. 1963), pp. 11–14, illus.

PHOTOGRAPHIC LABORATORY AND SALES DESK

The photographic laboratory made 10,403 items during the year as follows: 5,649 prints, 971 negatives, 3,451 color slides, 297 black-and-white slides, and 35 color sheet films. At the sales desk 67,589 items were sold, comprising 5,273 publications, and 62,316 reproductions (including postcards, slides, photographs, reproductions in the round, etc.). Chief photographer Raymond A. Schwartz spent 7 months in Japan and Taiwan on the Taiwan Photographic Project, and thus the production of the photographic laboratory was proportionately decreased; however, the figures for the sales desk indicate an increase of approximately 20 percent over the sales of the preceding year.

BUILDING AND GROUNDS

The exterior of the building appears to be sound and in good condition. The exterior masonry, including the walls of the courtyard has been cleaned. Blisters have appeared on the roof, but no serious damage has occurred; however, this condition will bear continuous watching.

In the interior, the structural steel in the attic remains in need of painting. An experimental system to be used in relamping consisting of a metal superstructure was installed over Galleries VIII, IX, and X, and has proved to be unsatisfactory. All steam pipes in the attic were removed and heating units installed in the existing ducts. This commendable measure made many areas more accessible for storage and general use.

Galleries I through VIII and XIII through XIX, including the east and west corridors, have been redecorated with vinyl resin-coated fabric to match Galleries IX, X, and XI. All baseboards, grills, and belt courses were painted as work progressed. The galleries now appear much improved and in good condition.

The exposed ceiling of the American painting storage was reinstalled and the area painted. Safety latches were designed and installed on each of the picture racks. Repair and refinishing of the panel storage cases has begun; work on the cases on the north and south sides of the room has been completed. Nine sets of doors remain to be refinished.

The wall, trim, doors, and window frames of the auditorium have been painted, and a new Altec No. 342B Amplifier-Preamplifier was installed and connected into the existing sound system. The north wall and ceiling at the back of the auditorium have been repaired.

The cabinet shop made and repaired furniture and equipment as the need arose.

Seasonal plantings in the courtyard were made and have flourished, and the entire courtyard was bird-proofed.

ATTENDANCE

The Gallery was open to the public from 9:00 to 4:30 every day except Christmas Day. The total number of visitors to come in the main entrance was 168,625. The highest monthly attendance was in July—22,329.

There were 3,224 visitors who came to the Gallery office for such varied purposes as to seek general information, to submit objects for examination, to consult staff members, to take photographs or sketch in the galleries, to use the library, to examine objects in storage, etc.

AUDITORIUM

The series of illustrated lectures was continued as follows:

1963

October 8---------- William G. Archer, Esq., Victoria and Albert Museum, London, England, "Rajput Painting." Attendance, 17.

November 12------- Donald H. Rochlen, Esq., United States Information Agency, "Thailand, an Archeological Treasure House." Attendance, 270.

1964

January 14 — Dr. Harold P. Stern, Freer Gallery of Art, "Life in 14th Century Japan." Attendance, 132.

February 11 — Dr. Aschwin Lippe, Metropolitan Museum of Art, "Early Chalukya Sculpture of India (Sixth and Seventh Centuries)." Attendance, 46.

March 10 — Michael Gough, Esq., British Institute of Archaeology, Ankara, Turkey, "Christian Archaeology in Asia Minor; the Last Ten Years." Attendance, 218.

April 14 — Fujio Koyama, Esq., Ceramics Historian, Tokyo, Japan, "Three-color Pottery in the Shōsōin." Attendance, 91.

The Smithsonian Institution used the auditorium as follows:

1963

September 27 — National Air Museum—lecture by Elmer A. Sperry, Jr., "Early Airplane Instruments." Attendance, 112.

The auditorium was used by seven outside organizations for 39 meetings as follows:

1963

United States Department of Agriculture:

United Givers Fund	September 19; attendance, 50.
4-H Club Group	October 24; attendance, 111.
National Outlook Conference	November 20; attendance, 230.
	November 21; attendance, 83.
Annual Farmers' Cooperative Workshop.	December 9; attendance, 120.

United States Department of Health, Education, and Welfare:

Food and Drug Administration, Bureau of Biological and Physical Sciences.	November 13; attendance, 138
E.D.A./F.P.B.	December 10; attendance, 81.
Women's Committee, National Symphony Orchestra.	October 2; attendance, 95.
Washington Chapter, National Women's Committee, Brandeis University.	October 2; attendance, 91.

1964

United States Department of Agriculture:

Federal Extension Service	January 8; attendance, 92.
	January 9; attendance, 85.
	January 10; attendance, 97.
	February 5; attendance, 63.
Forest Service	January 22; attendance, 64.
	March 2; attendance, 189.
Rural Electrification Administration.	February 4; attendance, 71.
Public hearing	April 9; attendance, 225.
	April 10; attendance, 81.

Office of the Inspector General.	April 28; attendance, 43. April 29; attendance, 70. April 30; attendance, 83. May 1; attendance, 63. May 5; attendance, 75. May 6; attendance, 84. May 7; attendance, 95. May 8; attendance, 59.
United States Department of Health, Education, and Welfare:	
Food and Drug Administration, Bureau of Biological and Physical Sciences.	January 15; attendance, 93. February 19; attendance, 137.
Division of Pharmacology	January 24; attendance, 81.
General meeting	April 15; attendance, 76.
Washington Fashion Group:	
Ninth Fashion Career Course:	
"Fashion Showmanship"	February 17; attendance, 242.
"Accessories to Fashion"	February 24; attendance, 256.
"Fashion in the Home"	March 2; attendance, 235.
"Fashion Communication"	March 9; attendance, 234.
"Fashion Careers Unlimited."	March 16; attendance, 234.
"Fashion Designing"	March 23; attendance, 237.
Archaeological Institute of America:	
Lecture by Professor D. P. Hansen, New York University, "Sculpture from Nippur."	April 16; attendance, 35.
National Academy of Sciences:	
Committee on Vision	April 23; attendance, 122. April 24; attendance, 160.

STAFF ACTIVITIES

The work of the staff members has been devoted to the study of new accessions, of objects contemplated for purchase, and of objects submitted for examination, as well as to individual research projects in the fields represented by the collection of Chinese, Japanese, Persian, Arabic, and Indian materials. In all, 17,894 objects and 1,298 photographs were examined, and 1,093 Oriental language inscriptions were translated for outside individuals and institutions. By request, 32 groups totaling 859 persons met in the exhibition galleries for docent service by the staff members. Ten groups totaling 98 persons were given docent service by staff members in the storage rooms.

Among the visitors were 132 distinguished foreign scholars or persons holding official positions in their own countries who came here under the auspices of the Department of State to study museum administration and practices in this country.

TECHNICAL LABORATORY

A total of 218 objects was examined by various methods, including microscopic and microchemical examination, and examination in ultraviolet light. Of the 85 Freer objects examined, 47 were bronze objects analysed by wet chemical methods, and 28 were objects of stone, bronze, silver, and other metalwork and pottery which were cleaned and/or repaired. Forty-two objects being considered for purchase were examined. Ninety-one objects were examined for other divisions of the Smithsonian, other museums, and private owners. Two of these were repaired, and 10 written reports were made. Forty-seven of these objects were coins belonging to the Dumbarton Oaks Research Library and Collection, of which the specific gravity was determined. In addition, 22 bronze standards were analyzed by wet methods; and 75 identifications were made by X-ray diffraction. Twenty inquiries were answered by letter, and numerous inquiries by telephone.

Analysis by wet chemical methods of Chinese bronzes in the Freer collection was continued. Further systematic collection of data on the technology of ancient copper and bronze in the Far East was undertaken. Much of the information gained will be presented in a forthcoming catalog on *Ancient Chinese Bronze Ceremonial Vessels in the Freer Gallery of Art*. Continued studies on the corrosion products of ancient metal objects were made. The editing of *IIC Abstracts*, published by the International Institute of Conservation of Historic and Artistic Works, London, continued to be carried on in the Technical Laboratory.

LECTURES BY STAFF MEMBERS

By invitation, the following lectures were given outside the Gallery by staff members (illustrated unless otherwise noted):

1963

June 25–August 25	W. B. Trousdale gave a series of 16 lectures on Chinese Art History, for the Second Summer Institute in Chinese Civilization, under the auspices of the United States Education Foundation in China, Taichung, Taiwan. Average attendance, 29; total attendance, 464.
July 12	Mr. Trousdale, at the China Society, Taichung Branch, Tunghai University, Taiwan, "Archaic Chinese Jade." Attendance, 50.
July 22	Dr. Richard Ettinghausen, at Georgetown University (Peace Corps Training Program), Washington, D.C., "Turkish Art." Attendance. 100.
July 22	R. J. Gettens, at the meeting of the ICOM Committee for Scientific Museum Laboratories held in Leningrad, U.S.S.R., read a paper on "Mineral Alteration Products on Ancient Metal Objects." Attendance, 75.

Wild Goats. Persian metalwork, Achaemenid period, 6th/5th century B.C. 63.15 and 64.6 Freer Galley of Art.

The Bodhisattva Fugen. Japanese painting, Heian period, 12th century Buddhist school. 63.3, Freer Gallery of Art.

Vase, by Ninsei Nonomura. Japanese pottery, Edo period, 17th century. 64.1, Freer Gallery of Art.

Landscape, by Liu Chüeh (1410–1472). Chinese painting. Ming dynasty. 64.2, Freer Gallery of Art.

1963	
October 7	Dr. John A. Pope, at the Society for Asian Art, Berkeley, Calif., "Japanese Porcelain and the Dutch Trade." Attendance, 75.
October 8	Dr. Pope, at Stanford University, Stanford, Calif., "The Monuments of Angkor." Attendance, 750.
October 9	Dr. Pope, at the University of California, Berkeley, Japanese Porcelain and the Dutch Trade." Attendance, 200.
October 13	Dr. Ettinghausen, at the Alburz Foundation, Teheran, Iran, "The Meaning of Art and Archaeology" (not illustrated). Attendance, 65.
October 14	Dr. Pope, at the Santa Barbara Museum of Art, Santa Barbara, Calif., "The Monuments of Angkor." Attendance, 150.
October 14	Dr. Ettinghausen, at the Iran-American Society, Teheran, Iran, "The Interest of the United States in Iranian Art and Culture." Attendance, 165.
October 16	Dr. Pope, at the Collectors Group, Los Angeles County Museum, Los Angeles, Calif., "The Collectors and Collections of Chinese Art." Attendance, 40.
October 16	Dr. Ettinghausen, at the Faculty of Fine Arts of the University of Teheran, "Masterworks of Iranian Art in Washington." Attendance, 250.
October 17	Dr. Pope, at the University of California in Los Angeles, "The Early Trade in Chinese Porcelain." Attendance, 150.
October 17	Dr. Pope, at the Japan-America Society of Southern California, Los Angeles, "Japanese Porcelain and the Dutch Trade." Attendance, 250.
October 17	Dr. Ettinghausen, at the Literary College of the University of Teheran, "Persian Miniature Painting." Attendance, 135.
October 18	Dr. Pope, at the San Diego Fine Arts Gallery, San Diego, Calif., "The Early Trade in Chinese Porcelain." Attendance, 125.
October 19	Dr. Pope, at the Art Center in La Jolla, Calif., "Collectors and Collections of Chinese Art." Attendance, 150.
October 21	Dr. Pope, at the University of Arizona, Tucson, "The Monuments of Angkor." Attendance, 150.
October 31	Dr. Pope, at Cornell University, Ithaca, N.Y., "Note on the Early Trade in Chinese Porcelain." Attendance, 175.
November 4	Dr. Ettinghausen, at the Turkish-American Association, The Art Lovers' Club, Ankara, Turkey, "American Interest in Turkish Art" (not illustrated). Attendance, 150.
November 7	Dr. Ettinghausen, at Ankara University, Literary College, "Persian Miniatures" (in German). Attendance, 100.

1963	
November 14	Dr. H. P. Stern, at the Royal Ontario Museum, Toronto, Canada, "Popular Painting of Tokugawa Japan." Attendance, 175.
December 5	Dr. Ettinghausen, at the Oriental Seminar of the University of Frankfurt, Germany, "The Development of Persian Miniature Painting" (in German). Attendance. 25.
December 12	Dr. Pope, at Princeton University, Princeton, N.J., "Some Aspects of the Pre-Eighteenth Century World Trade in Chinese Porcelain." Attendance, 175.
1964	
January 30	Dr. Pope, at the Williamsburg Antiques Forum, Williamsburg, Va., "The Far East and Early America; Especially Porcelain." Attendance, 350.
March 13	Mr. Gettens, at a symposium on "Aims and Essential Information for Reports on Technical Studies of Archaeological Objects," at Columbia University, New York City, "Requirements for Published Data on Chemical Analysis of Archaeological Objects." Attendance, 30.
March 13	Dr. Pope, at a symposium on "Chinese Export Porcelain," at Winterthur, Del., "Shapes and Decoration Common to Porcelain Made for Export to the Middle East, Portugal, Holland, and England to 1750." Attendance, 100.
April 7	Dr. Stern, at the Musée Guimet, Paris, France, "Japanese Art." Attendance, 10. (Staff members only.)
April 17	Dr. Stern, at the Rijksmuseum, Amsterdam, The Netherlands, "Hokusai." Attendance, 125.
April 20	Dr. J. F. Cahill, at the Norton Gallery of Art, West Palm Beach, Fla., "Chinese Painting and Contemporary Art." Attendance, 70.
April 22	Dr. Cahill, at the "Coffee Hour Talk," Princeton University, Princeton, N.J., "Photographing in Taiwan." Attendance, 30.
April 23	Mr. Gettens, at the 1964 National Junior Science and Humanities Symposium, Industrial College of the Armed Forces, Fort McNair, "Prying into Chinese Ceremonial Bronzes, the Documents of an Ancient Culture." Attendance, 35.
May 1–2	Dr. Cahill, at the University of Chattanooga Faculty Seminar, Chattanooga, Tenn., "Chinese and Japanese Art: Concurrences and Divergences," and "Chinese and Japanese Paintings." Attendance, respectively, 150 and 14.
May 4	Dr. Stern, at the Nationalmuseet, Copenhagen, Denmark, "Life in 14th Century Japan." Attendance, 150.
May 6	Dr. Stern, at the Museum of Decorative Art, Copenhagen, "Hokusai." Attendance, 150.
May 12	Dr. Stern, at Oxford University, England, "Hokusai." Attendance, 75.
May 13	Dr. Stern, at Oxford University, "Life in 14th Century Japan." Attendance, 80.
May 14	Dr. Stern, at the Japan Society of England, London, "Hokusai." Attendance, 65.

1964	
June 14	Dr. Ettinghausen, at the National Gallery of Art, "The Last Flowering of Iranian Art." Attendance, 375.
June 20	Dr. Cahill, at the Conference on the China for Presidents, Deans and Senior Faculty Members of New York State Colleges, Pinebrook, Saranac Lake, N.Y., "Chinese Art and Its Background in Thought." Attendance, 35.

Members of the staff traveled outside Washington on official business as follows:

1963	
May 8–July 9	Dr. J. A. Pope, in Europe, attended the opening of the new Museum of Far Eastern Antiquities, in Stockholm, Sweden. He also saw other collections in Sweden, Denmark, The Netherlands, Austria, Switzerland, France, and England: in numerous museums, private collections, and dealers.
June 14–July 15	Miss E. H. West, in Europe, visited numerous museums in Italy, France, and England; she also attended a symposium on art conservation sponsored by the Conservation Center of the Institute of Fine Arts, New York University, held at the Institut Royal du Patrimoine Artistique, in Brussels, Belgium.
June 17–November 22.	W. B. Trousdale, in the Orient and Europe, examined objects in museums and private collections, and visited archeological sites, in Japan, Taiwan, India, Afghanistan, Iran, Lebanon, Turkey, Switzerland, Sweden, and England.
June 29–July 1	Dr. J. F. Cahill, in New York City, attended the exhibition, "Evolution of the Buddha Image," at Asia House Gallery; and examined objects for numerous dealers.
July 15–19	Mrs. B. M. Usilton, in Chicago, Ill., attended the annual meetings of the American Library Association.
August 10	Dr. Pope, in Williamsburg, Va., examined pottery for Colonial Williamsburg.
August 20	Dr. H. P. Stern, in New York City, examined miscellaneous objects for a dealer.
August 21–22	Dr. Stern, in Philadelphia, examined miscellaneous objects at the Museum of Art and at the University Museum; the latter included the collection of Edmund Zalinski.
August 29–November 22.	T. Sugiura, in Japan, met with other restorers, ordered special silks and other supplies unobtainable in the United States, and saw numerous objects in museums, private collections, and dealers.
September 1–October 16.	Mr. Gettens, in Europe, attended meetings of the ICOM Committee for Scientific Museum Laboratories held in Leningrad and Moscow. He also visited museums and laboratories in these two cities, and in Vienna, Münich, Zürich, Stuttgart, Brussels, Paris, London, and Dublin, examining objects at the British Museum in London, the Musée Cernuschi in Paris, and the Institut Royal du Patrimoine Artistique in Brussels.

1963	
September 2–March 30.	Dr. Cahill, in Japan, Formosa (Taiwan), and Hong Kong, attended a number of exhibitions, including "Art of the Ming and Ch'ing Dynasties" and "Indian Art" at the Tokyo National Museum; saw numerous objects in museums and private collections; and participated in the Taiwan Photographic Project to aid in the establishment of two archives of photographic negatives of objects in the National Palace and Central Museums, one archive to be kept in Taiwan, and the other to be deposited with an institution in the United States; this project was financed by the Rockefeller, Bollingen, and Henry Luce Foundations, with the Freer Gallery of Art administering the funds.
September 2–April 24.	R. A. Schwartz, in Japan and Formosa (Taiwan), attended a number of exhibitions and saw numerous objects in museums and private collections; photographed Chinese paintings in the exhibition, "Art of the Ming and Ch'ing Dynasties" at the Tokyo National Museum; and participated in the Taiwan Photographic Project, doing the actual photographic work; photographed numerous kiln sites and outstanding examples of old palace architecture; approximately 7,000 color and 9,000 black-and-white negatives, a total of 16,000, were made on the taiwan project.
September 7–9	Dr. Pope, in New York City, examined miscellaneous Chinese and Japanese objects at the Metropolitan Museum of Art and at one dealer's.
September 9–20	Dr. Stern, in Ann Arbor, Mich., taught a 2-week seminar on Ukiyoe painting, at the University of Michigan.
September 18–December 16.	Dr. Ettinghausen, in Venice, Italy, attended the Second International Congress of Turkish Art; helped plan two traveling exhibitions. "7,000 Years of Iranian Art" and "Art Treasures from Turkish Museums," to be shown in the United States: saw collections in museums in Iran, Turkey, Italy, Switzerland, Germany, France, and England, and examined objects for numerous private collectors and dealers.
October 7–24	Dr. Pope, in California, visited the collections and examined objects in the Brundage Collection of the M. H. DeYoung Memorial Museum, the Stanford University Museum, the Santa Barbara Museum of Art, and the San Diego Museum of Art; also examined objects at numerous dealers and in private collectors, including one in Tucson, Ariz.
October 16–19	Mrs. Usilton, in Atlantic City, N.J., attended meetings of the Middle Atlantic Regional Library Conference.
October 18–19	Dr. Stern, in New York City, examined objects at several dealers.
October 31	Dr. Pope, in Ithaca, N.Y., examined Chinese pottery at the Andrew Dixon White Museum of Art, Cornell University.
November 1–2	Dr. Pope, in New York City, examined objects at several dealers.

1963

November 4–8------- Dr. Stern, in Ann Arbor, taught a one-week seminar on Japanese painting, at the University of Michigan.

November 13–15----- Dr. Stern, in Toronto, Canada, examined numerous Chinese and Japanese objects at the Royal Ontario Museum.

November 18-------- Dr. Pope, in Greenville, Del., examined objects in a private collection and at the Winterthur Museum.

November 29–December 2. Dr. Pope, in Kansas City, Mo., examined objects at the William Rockhill Nelson Gallery of Art and in a private collection; and in Chicago examined objects at the Art Institute and at a dealer.

1964

January 2---------- Mrs. E. West FitzHugh, in Baltimore, Md., visited the Walters Art Gallery, regarding the conservation of Armenian manuscripts, and the new laboratory at the Baltimore Museum of Art.

January 18–22------ Dr. Pope, in Cambridge, Mass., attended a meeting of the *ad hoc* Committee on Tenure Appointments, Harvard University; and in New York City examined objects at several dealers.

January 28–30------ Dr. Pope, in Williamsburg, attended the Antiques Forum, during which time he examined objects for the Department of Archaeology, Colonial Williamsburg.

January 30–31------ Dr. Ettinghausen, in Philadelphia, attended the annual meeting of the College Art Association and examined objects at the Free Library of Philadelphia and in a private collection.

February 7–8------- Dr. Ettinghausen, in New York City, attended the exhibition of Mughal painting at Asia House; met with Prof. Edith Porada, Columbia University, regarding the catalog of the exhibition, "7,000 Years of Iranian Art"; and examined objects at several dealers.

February 15–16----- Dr. Pope, in New York City, attended meetings of the American Council of Learned Societies S.S.R.C. Committee for Grants on Asian Studies.

March 3------------ Dr. Pope, in Buffalo, N.Y., examined objects in the von der Heydt Collection at the Museum of Science.

March 13----------- Dr. Pope, at Winterthur, Del., examined objects for the Winterthur Museum and in a private collection.

March 13----------- Mr. Gettens, in New York City, attended a symposium at Columbia University.

March 23–25-------- Dr. Pope, in New York City, examined objects at several dealers and in a private collection.

March 26–June 16--- Dr. Stern, in Europe, saw collections in Lisbon, Portugal; Paris, France; Amsterdam, The Netherlands; Copenhagen, Denmark; and London, England: in numerous museums and private collections and at dealers.

April 8–9---------- Dr. Pope, in New York City, attended meetings of the American Oriental Society and reported in his capacity as chairman of the Louise Wallace Hackney Scholarship Committee; examined objects at the Metropolitan Museum of Art and at one dealer and a private collection.

1964	
April 19–21	Dr. Cahill, in West Palm Beach, Fla., examined objects at the Norton Gallery of Art and in a private collection.
April 22	Dr. Cahill, in Princeton, N.J., examined objects in a private collection.
April 24–25	Dr. Pope, in Philadelphia, recorded two taped programs for "What in the World" at WCAU–TV broadcasting station; and in New York City attended the board meeting of the College Art Association.
May 7–8	Mr. Trousdale, in New York City, did preliminary work on a film narration for the Asia Society; and examined a large private collection of jade.
May 17–June 30	R. C. Mielke saw building installations at the Dayton Art Institute, Cincinnati Art Museum, John Herron Art Institute, City Art Museum of St. Louis, William Rockhill Nelson Gallery of Art, Art Institute of Chicago, Detroit Institute of Arts, Cleveland Museum of Art, and Toledo Museum of Art.
May 21–22	Dr. Cahill, in New York City, attended a meeting of the American Council of Learned Societies, Committee on Studies of Chinese Civilization; saw the exhibition "Art of Nepal" at Asia House; and examined objects at several dealers.
May 25–26	Mrs. E. West FitzHugh, in St. Louis, Mo., attended the annual meeting of the International Institute for the Conservation of Museum Objects, American Group.
May 25–27	Mrs. L. O. West and Mrs. M. H. Quail, in Chicago, Ill., attended meetings of the Museums Sales Association.
May 25–29	Mr. Gettens, in St. Louis, Mo., attended meetings of the I.I.C., American Group, and the American Association of Museums; he also examined objects at the City Art Museum of St. Louis and the Allen Art Museum, Oberlin College, Oberlin, Ohio.
June 8	Dr. Pope left for Europe to visit museums and collections in England and France.
June 19	Mrs. FitzHugh, in Baltimore, Md., visited the Walters Art Gallery where she worked in the conservation laboratory on the chemical microscopy of pigments.
June 29	Dr. Ettinghausen, in New York City, examined objects at several dealers.

As in former years, members of the staff undertook a wide variety of peripheral duties outside the Gallery, served on committees, held honorary posts, and received recognitions.

Respectfully submitted.

John A. Pope, *Director.*

S. Dillon Ripley,
Secretary, Smithsonian Institution.

Report on the National Gallery of Art

SIR: I have the honor to submit, on behalf of the Board of Trustees, the 27th annual report of the National Gallery of Art, for the fiscal year ended June 30, 1964. This report is made pursuant to the provisions of section 5(d) of Public Resolution No. 14, 75th Congress, 1st session, approved March 24, 1937 (50 Stat. 51).

ORGANIZATION

The statutory members of the Board of Trustees of the National Gallery of Art are the Chief Justice of the United States, the Secretary of State, the Secretary of the Treasury, and the Secretary of the Smithsonian Institution, ex officio. On January 9, 1964, Lessing J. Rosenwald and Dr. Franklin D. Murphy were elected general trustees of the National Gallery of Art. The three other general trustees continuing in office during the fiscal year ended June 30, 1964, were Paul Mellon, John Hay Whitney, and John N. Irwin II. On May 7, 1964, Paul Mellon was reelected by the Board of Trustees to serve as president of the Gallery, and John Hay Whitney was reelected vice president. On January 9, 1964, J. Carter Brown was elected assistant director.

The executive officers of the Gallery as of June 30, 1964, were as follows:

Chief Justice of the United States, Earl Warren, Chairman.
Paul Mellon, President.
John Hay Whitney, Vice President.
Huntington Cairns, Secretary-Treasurer.
John Walker, Director.
Ernest R. Feidler, Administrator.
Huntington Cairns, General Counsel.
Perry B. Cott, Chief Curator.
J. Carter Brown, Assistant Director.

The three standing committees of the Board, as constituted at the annual meeting on May 7, 1964, were as follows:

EXECUTIVE COMMITTEE

Chief Justice of the United States, Earl Warren, Chairman.
Paul Mellon, Vice Chairman.
Secretary of the Smithsonian Institution, S. Dillon Ripley.
John Hay Whitney.
Dr. Franklin D. Murphy.

FINANCE COMMITTEE

ACQUISITIONS COMMITTEE

PERSONNEL

At the close of fiscal year 1964, full-time Government employees on the permanent staff of the National Gallery of Art numbered 305. The U.S. Civil Service regulations govern the appointment of employees paid from appropriated funds.

Continued emphasis was given to the training of employees under the Government Employees Training Act, and it was possible to give training to seven employees under that Act.

APPROPRIATIONS

For the fiscal year ended June 30, 1964, the Congress of the United States, in the regular annual appropriation, and a supplemental appropriation required for pay increases for wage-board employees, provided $2,176,000 to be used for salaries and expenses in the operation and upkeep of the National Gallery of Art, the protection and care of works of art acquired by the Board of Trustees, and all administrative expenses incident thereto, as authorized by the basic statute establishing the National Gallery of Art.

The following obligations were incurred:

Personnel compensation and benefits	$1, 831, 443. 17
All other items	315, 774. 41
Total obligations	2, 147, 217. 58

Because the low bid for the contract to renovate the skylights over the east wing of the Gallery was considerably below the amount included in the appropriation for that purpose, it was possible to return $28,782 to the Treasury as an unobligated balance.

ATTENDANCE

There were 1,236,155 visitors to the Gallery during fiscal year 1964. The attendance for the previous fiscal year was higher by 557,345 visitors. This resulted from the large number of people who came to see the *Mona Lisa* by Leonardo da Vinci when it was on exhibition at the National Gallery of Art for 27 days in fiscal year 1963. The daily average number of visitors during the past fiscal year was 3,415. This is the largest average in the past 10 years, except those years in which occurred the unusually popular exhibitions of the *Mona Lisa* and the Tutankhamen Treasures.

ACCESSIONS

There were 5,002 accessions by the National Gallery of Art as gifts, loans, or deposits during the fiscal year, an increase of 3,796 over the previous year.

GIFTS

During the year the following gifts or bequests were accepted by the Board of Trustees:

PAINTINGS

Donor	*Artist*	*Title*
Avalon Foundation, New York, N.Y.	Cropsey	Autumn on the Hudson River.
Do	Doughty	Fanciful Landscape.
John W. Beatty, Jr., Pittsburgh, Pa.	Homer	Marshy Scene with Man in Boat.
National Gallery of Art, Ailsa Mellon Bruce Fund.	Poussin	The Assumption of the Virgin.
Paul Mellon, Upperville, Va.	Canaletto	Landscape Capriccio with Column.
Do	do	Landscape Capriccio with Palace.
Do	Devis	Conversation Piece, Ashdon House.
Do	do	Lord Brand of Hurndall Park.
National Gallery of Art, Andrew Mellon Fund.	Rubens	Tiberius and Agrippina.
National Gallery of Art, Adolph Caspar Miller Fund.	Copley	Watson and the Shark.

GRAPHIC ARTS

Donor	*Artist*	*Title*
Mrs. George Matthew Adams, New York, N.Y.	Legros	Cardinal Manning.
Do	do	Hand of His Daughter.
Mrs. George Matthew Adams, New York, N.Y.	Legros	Nude.
John W. Beatty, Jr., Pittsburgh, Pa.	Various	Nineteen prints and drawings.
Mr. and Mrs. Frank Eyerly, Des Moines, Iowa.	Miro	Ink and pastel drawing.
Do	Feininger	Spire of Gelmeroda.
Mrs. Beatrice Beck Fahnestock, Washington, D.C.	Watteau	A Mezzetin.
Samuel H. Kress Foundation, New York, N.Y.	Various	Thirty-four French and Italian drawings and water colors.
Mrs. Laura T. Magnuson, Washington, D.C.	Renoir	Red-chalk drawing of a child.
Print Council of America, New York, N.Y.	Various	Set of 55 prints in the exhibition "American Prints Today—1962."
Lessing J. Rosenwald, Jenkintown, Pa.	do	2,574 prints, drawings, illustrated books, and reference works. Among the prints are important works by Aldegrever, Baldung Grien, Dürer, Bruegel, Bosch, Rembrandt, Goya, Daumier, and Degas.
David E. Rust, Washington, D.C.	Gentileschi, Orazio.	A Young Girl Playing a Lute.

EXCHANGE OF WORKS OF ART

In exchange for a print by Daumier entitled "Un plaideur peu satisfait" in the Rosenwald Collection, Mr. Rosenwald gave a woodcut by Christoffel Jegher, after Rubens, entitled "The Rest on the Flight into Egypt."

OTHER GIFTS

In the fiscal year 1964 gifts of money were made by Avalon Foundation, Mrs. Cordelia S. May, Old Dominion Foundation, Calouste Gulbenkian Foundation, J. I. Foundation, Inc., The Frelinghuysen Foundation, Samuel H. Kress Foundation, 16th International Congress of Zoology, and Mrs. Landon C. Bell.

Mrs. Mellon Bruce contributed additional funds for the purchase of works of art for the National Gallery of Art and for educational purposes related to works of art

The Gallery received a bequest of funds by the late Chester Dale to provide fellowships for painters, sculptors, and historians and critics of the fine arts.

WORKS OF ART ON LOAN

The following works of art were received on loan by the Gallery:

From	*Artist*	*Title*
Mr. and Mrs. David Lloyd Kreeger, Washington, D.C.	Bonnard	Le Jardin de Bosquet.
Do	Cézanne	La Route Tournante.
Do	Van Gogh	Vase of Flowers.
Do	Maillol	Pomona (sculpture).
Do	Picasso	Café de la Rotonde.
Do	Renoir	Bather.
Do	do	View of Venice.
Mrs. Eugene E. Meyer, Washington, D.C.	Dufresne	Still Life.
Do	Renoir	Man Lying on Sofa.
Do	do	Nude.
The Honorable Claiborne Pell, Washington, D.C.	Bingham	The Jolly Flatboatman.
S. Dillon Ripley, Washington, D.C.	Audubon	Washington Sea Eagle.

WORKS OF ART ON LOAN RETURNED

The following works of art on loan were returned during the fiscal year:

To	*Artist*	*Title*
Col. and Mrs. Edgar W. Garbisch, New York, N.Y.	Senior	The Sportman's Dream.
Mr. and Mrs. David Lloyd Kreeger, Washington, D.C.	Bonnard	Le Jardin de Bosquet.
Do	Cézanne	La Route Tournante.
Do	Van Gogh	Vase of Flowers.
Do	Picasso	Café de la Rotonde.
Do	Renoir	Bather.
Do	do	View of Venice.
Mrs. Eugene E. Meyer, Washington, D.C.	Dufresne	Still Life.
Do	Renoir	Man Lying on Sofa.
Do	do	Nude.

WORKS OF ART LENT

The American Federation of Arts, New York, N.Y., circulated the following works of art during the fiscal year to the Rochester Memorial Art Gallery, Rochester, N.Y.; Milwaukee Art Center, Milwaukee, Wis.; Isaac Delgado Museum of Art, New Orleans, La.; Baltimore

Museum of Art, Baltimore, Md.; Philadelphia Museum of Art, Philadelphia, Pa.; Museum of Fine Arts, Boston, Mass.; and Detroit Art Institute, Detroit, Mich.:

To	*Artist*	*Title*
American Federation of Arts, New York, N.Y.	Joseph Badger	Mrs. Isaac Foster.
Do	John Bradley	Little Girl in Lavender.
Do	Bundy	Vermont Lawyer.
Do	Earl	Family Portrait.
Do	Hofmann	Berks County Almshouse.
Do	Linton Park	Flax Scutching Bee.
Do	Susanne Walters	Memorial to Nicholas M. S. Catlin.
Do	Unknown	Jonathan Benham.
Do	do	The Start of the Hunt.
Do	do	The End of the Hunt.
Do	do	The Sargent Family.
Do	do	Alice Slade.
Do	do	Joseph Slade.
Do	do	General Washington on White Charger.
Do	do	Blue Eyes.
Do	do	The Hobby Horse.
Do	do	Mahantango Valley Farm.
Do	do	Civil War Battle Scene.

The following loans also were made during the fiscal year:

American Embassy, London, England.	Canaletto	Landscape Capriccio with Column.
Do	do	Landscape Capriccio with Palace.
Do	Devis	Conversation Piece, Ashdon House.
Do	do	Lord Brand of Hurndall Park.
Cleveland Museum of Art, Cleveland, Ohio.	Stuart	The Skater.
Museum of Fine Arts, Boston, Mass.	Homer	Right and Left.
Do	Unknown	Burning of Old South Church, Bath, Maine.
Columbia Museum of Art, Columbia, S.C.	Healy	Franklin Pierce.
Do	do	Daniel Webster.
Do	Lambdin	John Marshall.
Do	Stuart	Horace Binney.
Do	Sully	John Quincy Adams.
Do	Unknown	President John Tyler.
Corcoran Gallery of Art, Washington, D.C.	Sargent	Repose.
Do	do	Street in Venice.

To	*Artist*	*Title*
Detroit Institute of Arts, Detroit, Mich.	British School	Pocahontas.
Museum of Early American Folk Arts, New York, N.Y.	L. Sachs	The Herbert Children.
Do	Unknown	Baby in Blue Cradle.
Do	do	Child with Rocking Horse.
The Minneapolis Institute of Arts, Minneapolis, Minn.	Copley	Epes Sargent.
Do	West	The Battle of La Hogue.
Portland Museum of Art, Portland, Maine.	Unknown	Burning of Old South Church, Bath, Maine.
City Art Museum of St. Louis, St. Louis, Mo.	Stuart	Mrs. Yates.
Smithsonian Institution, Museum of History and Technology.	British School	Pocahontas.
Do	Peale	William Moultrie.
Do	Pine	General Smallwood.
Do	Polk	Washington at Princeton.
Smithsonian Institution, Museum of History and Technology, Presidential Reception Room.	Sully	Major Thomas Biddle.
Do	Jarvis	Commodore Rodgers.
Do	Healy	Daniel Webster.
Do	Peale	Robert Coleman.
Virginia Museum of Fine Arts, Richmond, Va.	British School	Pocahontas.
Washington County Museum of Fine Arts, Hagerstown, Md.	Peale	John Philip de Haas.
Do	do	General William Moultrie.
Do	do	Benjamin Harrison, Jr.
The White House, Washington, D.C.	Sully	Andrew Jackson.
Do	Healy	Henry Clay.
Do	Stuart	George Washington.
Whitney Museum of American Art, New York, N.Y.	Homer	Right and Left.

EXHIBITIONS

The following exhibitions were held at the National Gallery of Art during the fiscal year 1964:

Prints and Drawings by Mary Cassatt. Continued from the preceding fiscal year through September 12, 1963.

Landscape Prints. From the Rosenwald Collection. Continued from the preceding fiscal year through October 14, 1963.

Exhibition of Modern Prints and Illustrated Books from the Rosenwald Collection. July 13 through September 2, 1963.

Water Colors by J. M. W. Turner from the collection of the British Museum. September 15 through October 13, 1963.

Exhibition of Etchings and Mezzotints from J. M. W. Turner's "Liber Studiorum." September 15 through October 13, 1963.

Eighteenth-Century Venetian Drawings from the Correr Museum. October 27 through November 24, 1963.

Eighteenth-Century Venetian Etchings from the National Gallery of Art Collection. October 27 through November 24, 1963.

National Gallery of Art 1963 Christmas Card Subjects from the Graphic Arts. November 20 through December 10, and from December 17, 1963, through January 7, 1964.

Prints by Käthe Kollwitz from the Rosenwald Collection in Commemoration of Human Rights week. December 10 through December 18, 1963.

Paintings from The Museum of Modern Art, New York. December 17, 1963, through March 22, 1964.

Expressionist Prints from the Rosenwald Collection. December 17, 1963, through March 22, 1964.

Thomas Rowlandson Prints from the Rosenwald Collection. January 7 through April 17, 1964.

Drawings from the National Gallery of Art Collection. April 17, 1964, to continue into the next fiscal year.

7000 Years of Iranian Art. June 7, 1964, to continue into the next fiscal year.

Portrait of the Artist's Mother: Arrangement in Gray and Black, No. 1 by James Abbott McNeill Whistler. Lent by the Musée du Louvre. June 10 through June 30, 1964.

Whistler Prints from the National Gallery of Art Collection. June 10, 1964, to continue into the next fiscal year.

Exhibitions of recent accessions: "Joris W. Vezeler" and "Margaretha Boghe, Wife of Joris W. Vezeler" by Joos van Cleve. Continued from the preceding fiscal year through July 11, 1963; "The Bookseller's Wife" by Goya, August 30, through October 30, 1963; "The Assumption of the Virgin" by Poussin, November 17, 1963, through January 10, 1964.

TRAVELING EXHIBITIONS

Special exhibitions of graphic arts from the National Gallery of Art collections were circulated during the fiscal year to 50 museums, universities, schools, and art centers in the United States and abroad.

Index of American Design. Fifty-eight exhibitions (2,344 plates) of material from the Index were circulated to 18 States and the District of Columbia.

CURATORIAL ACTIVITIES

Under the direction of Perry B. Cott, chief curator, the curatorial department accessioned 2,700 gifts to the Gallery during the fiscal year 1964. Advice was given with respect to 1,918 works of art brought to the Gallery for expert opinion, and 20 visits to collections were made by members of the staff in connection with offers of gifts. About 6,691 inquiries, many of them requiring research, were answered verbally and by letter.

William P. Campbell, assistant chief curator, served as a member of the Special Fine Arts Committee of the Department of State.

Hereward Lester Cooke, curator of painting, continued as consultant to National Aeronautics and Space Administration with duties of organizing and supervising commissions to artists for paintings of themes relating to the space program. He also acted as judge for the Tri-State Exhibition, Evansville, Ind., and the Savannah Art Association exhibition during the fiscal year.

The Richter Archives received and cataloged 84 photographs on exchange from museums here and abroad; 2,289 photographs were purchased, and about 1,000 reproductions have been added to the archives.

RESTORATION

Francis Sullivan, resident restorer of the Gallery, made regular and systematic inspection of all works of art in the Gallery and on loan to Government buildings in Washington, and periodically removed dust and bloom as required. He relined, cleaned, and restored 18 paintings and gave special treatment to 37. Thirty-four paintings were X-rayed as an aid in research. He continued experiments with synthetic materials as suggested by the National Gallery of Art Research Project at the Mellon Institute, Pittsburgh, Pa. Technical advice was given in response to 237 telephone inquiries. Special treatment was given to works of art belonging to Government agencies, including the U.S. Capitol and the Treasury Department. In other instances advice was furnished to various agencies concerning the care and conservation of paintings.

PUBLICATIONS

A new book by John Walker, director, on the history and collections of the Gallery entitled *National Gallery of Art, Washington, D.C.* appeared during the year.

Mr. Cooke wrote an article for *Art in America*, October 1963 issue, entitled "Count-Down at Canaveral." He also wrote the text for 16 National Gallery leaflets.

Miss Katharine Shepard, assistant curator of graphic arts, wrote a book review for the *American Journal of Archaeology*, April 1964 issue.

PUBLICATIONS FUND

During the fiscal year 1964, the Publications Fund placed on sale six new publications including two books: *National Gallery of Art, Washington, D.C.* by John Walker and *The Eternal Present: The Beginnings of Architecture* by S. Giedion, the latter being the second volume of the 1957 A. W. Mellon Lectures in the Fine Arts. Four exhibition catalogs were placed on sale: *Turner Water Colors: Eighteenth-Century Venetian Drawings from the Correr Museum;*

Paintings from the Museum of Modern Art, New York; and *7000 Years of Iranian Art.* The number of 11- by 14-inch color reproductions published by the Gallery was increased to 238 with the addition of 37 new subjects, and 44 new postcards were published to make a total of 196 subjects now available. Two new slide sets of paintings by Rembrandt and by Renoir were placed on sale. The 1963 Christmas card selection included 14 new color subjects. With Gallery cooperation, six new collotype reproductions were produced: Botticelli—*Madonna and Child with Angels*, Canaletto—*The Portello and the Brenta Canal at Padua*, Van Cleve—*Joris W. Vezeler* and *Margaretha Boghe, Wife of Joris W. Vezeler*, Gentileschi—*The Lute Player*, and Redon—*Wildflowers.* Five small sculpture reproductions were added to the items available to the public.

EDUCATIONAL PROGRAM

The program of the educational department was carried out under the direction of Raymond S. Stites and his staff. Lectures and conducted tours on works of art in the Gallery's collections were given.

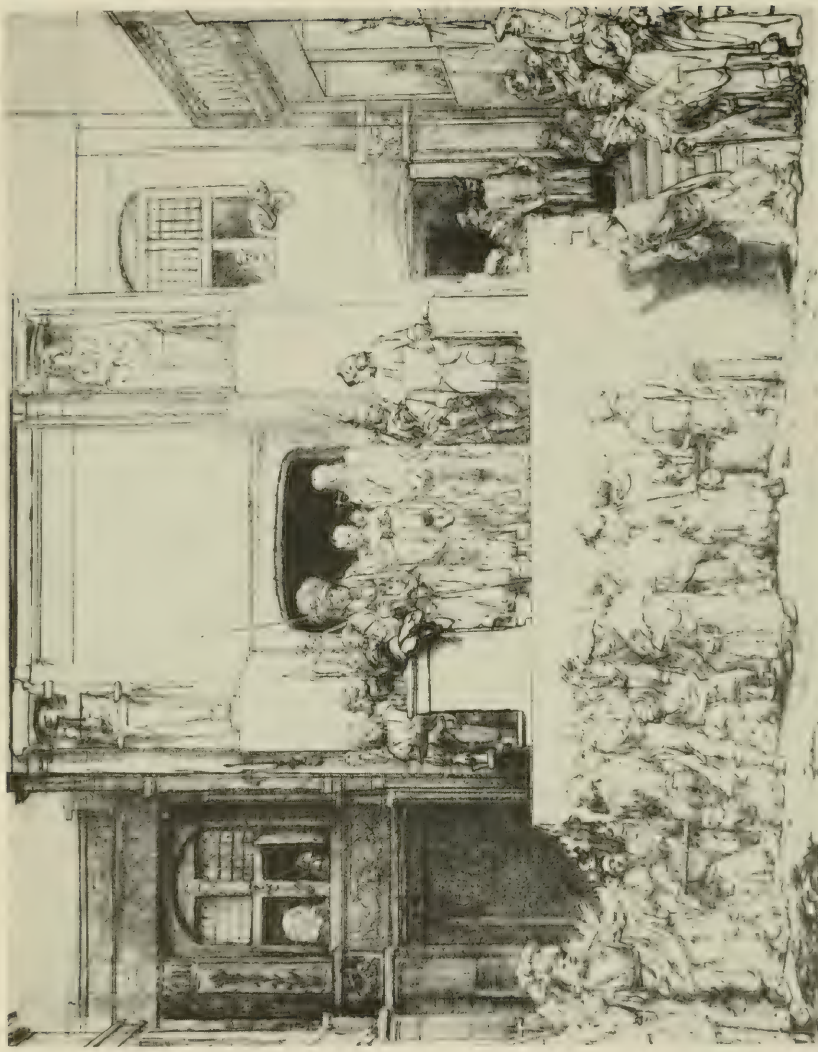
Attendance for the general tours, tours of the week, and picture-of-the-week talks amounted to 40,801. The attendance at the Sunday afternoon lectures in the auditorium totaled 13,450.

Special tours, lectures, and conferences were arranged for a total of 17,371 persons. These special appointments were made for Government agency groups, and at the request of congressional offices, for educators, foreign students, club and study groups, religious organizations, conventions, museum officials, and groups from hospitals, as well as school groups from various parts of the country.

The program of training volunteer docents continued, and special instruction was given to approximately 130 volunteers from the Junior League of Washington and the American Association of University Women. By special arrangement with the public and parochial schools of the District of Columbia and surrounding counties of Maryland and Virginia, these organizations conducted tours for 68,836 children, representing an increase over last year of 2,308. They also guided 750 Safety Patrol girls from Atlanta, Ga., on tours of the Gallery.

Fifty-two lectures were given in the auditorium on Sunday afternoons. Of these, 34 were delivered by guest lecturers, 10 by members of the staff, and two were full-length film presentations. Jakob Rosenberg delivered the 13th annual series of the A. W. Mellon Lectures in the Fine Arts on seven consecutive Sundays beginning on March 8 on the general subject: "*On Quality in Art: Criteria of Excellence in the Past and Present.*"

The Virgin and Child with a Rose. An etching by Jacques Bellange (1594–1638). Rosenwald Collection. National Gallery of Art.



Christ Presented to the People. An etching, early state—1655—by Rembrandt van Ryn (1606–1669). Rosenwald Collection. National Gallery of Art.

Lord Brand of Hurndall Park, by Arthur Devis (1711–1787). Gift of Paul Mellon. National Gallery of Art.

Conversation Piece, Ashdon House, by Arthur Devis (1711–1787). Gift of Paul Mellon. National Gallery of Art.

Landscape Capriccio with Palace, by Canaletto (1697–1768). Gift of Paul Mellon. National Gallery of Art.

Landscape Capriccio with Column, by Canaletto (1697–1768). Gift of Paul Mellon. National Gallery of Art.

Autumn on the Hudson River, by Jasper Francis Cropsey (1823–1900). Gift of the Avalon Foundation. National Gallery of Art.

Fanciful Landscape, by Thomas Doughty (1793–1856). Gift of the Avalon Foundation. National Gallery of Art.

Tiberius and Agrippina, by Rubens. Andrew Mellon Purchase Fund. National Gallery of Art.

The Assumption of the Virgin, by Nicolas Poussin. Gift of Mrs. Mellon Bruce. National Gallery of Art.

The slide library of the educational department has a total of 47,624 slides in its permanent and lending collections. During the year 1,942 slides were added to the collections. Altogether, 458 persons borrowed a total of 11,494 slides from the collections. It is estimated that these slides were seen by 21,420 viewers.

Members of the staff participated in outside activities delivering lectures, teaching courses in local schools at night, and attending College Art Association meetings. Staff members prepared and recorded scripts for Lectour recordings and radio talks, and prepared the material for the school tour program and the slide lending program.

A printed calendar of events was prepared and distributed monthly to a mailing list of more than 7,900 names.

EXTENSION SERVICES

The office of extension services, under the direction of the curator of the Index of American Design, Grose Evans, circulated to the public traveling exhibitions, films, slide lectures, and filmstrip sets of works of art in the National Gallery of Art's collections. There are 44 traveling exhibits in circulation, lent free of charge except for shipping expenses. These were circulated in 399 bookings and were seen by an estimated 199,500 viewers. Eleven special exhibits, lent to a church organization for circulation in 96 bookings, were seen by 37,552 viewers. Thirteen copies each of exhibits were lent to 13 New York State schools, having a total of 13,768 students—estimated viewers, 55,072. Two films on the National Gallery were circulated in 171 bookings and were seen by an estimated 51,300 viewers. A total of 1,174 slide lecture sets were circulated in 3,435 bookings and were seen by an estimated 206,100 viewers. The extension service reached approximately 549,524 persons during the year; this is an increase of 164,964 over the number of persons served last year.

The curator of the Index prepared the texts for the slide lectures and new circulating exhibits; also he attended conferences to demonstrate the extension services and to keep abreast of new developments in the audiovisual field.

LIBRARY

During the year the library, under the supervision of Ruth E. Carlson, accessioned 3,724 publications, of which 3,548 were obtained through exchange, by gift, or purchased from private funds. Government funds were used to purchase 23 books and 26 subscriptions to periodicals, and for the binding of 127 volumes of periodicals. A total of 2,373 photographs were added to library stock and to the archives and were acquired by exchange or purchased from private funds.

766–746—65——16

During the year 1,944 publications were cataloged and classified; 7,100 cards were filed in the main catalog and the shelf-list. Library of Congress cards were used for 508 titles; original cataloging was done for 454 titles. There were 3,169 periodicals recorded, 11,187 periodicals circulated, and 5,291 books charged out to the staff. There were 6,193 books shelved in normal routine. The Gallery borrowed 1,512 books on interlibrary loan. The exchange program was continued during the year, and 1,689 National Gallery publications were distributed. The Gallery received 2,454 publications of various types under this program.

The library is the depository for black-and-white photographs of works of art in the Gallery's collections. These are maintained for use in research by the staff, for exchange with other institutions, for reproduction in approved publications, and for sale to the public. Approximately 6,000 photographs were added to the stock in the library during the year, and 1,420 orders for 6,018 photographs were filled. There were 411 permits for reproduction of 1,058 subjects processed in the library.

INDEX OF AMERICAN DESIGN

The Index of American Design, under the supervision of Grose Evans, circulated, in addition to the traveling exhibits referred to above, 140 sets of color slides (7,073) throughout the United States, and 518 photographs of Index materials were used for exhibits, study, and publication. The photographic file has been increased by 110 negatives and 116 prints; 22 permits to reproduce 73 subjects from the Index were issued. Special exhibits of Index material were prepared at the request of various groups involving a total of 178 water colors. The material of the Index was studied during the year by 319 persons conducting research, collecting material for publication and design, and for illustration. The curator of the Index held conferences with important scholars, attended meetings, conducted a television course in conjunction with George Washington University, and lectured to a variety of groups, including USIA personnel.

MAINTENANCE OF THE BUILDING AND GROUNDS

The Gallery building, mechanical equipment, and grounds have been maintained throughout the year at the established standards.

The Gallery entered into contracts for the renovation of the skylight on the east wing of the building and to construct six new galleries for the exhibition of the Chester Dale Collection of paintings. Work under these contracts will be completed during the next fiscal year.

The Gallery staff made special preparations in the ground floor galleries and the central gallery for the exhibition of paintings from

the Museum of Modern Art and the exhibition entitled *7000 Years of Iranian Art.*

The Gallery greenhouse continued to produce flowering and foliage plants in quantities sufficient for all decorative needs of special openings and day-to-day requirements of the Garden Courts.

The program of increased security protection for the Gallery and its works of art was furthered during the fiscal year by the acquisition of a guard dog. This dog and his handler, a Gallery employee, were graduated from the regular training school of the District of Columbia Metropolitan Police K–9 Corps and are now on duty at the Gallery building.

LECTOUR

During the fiscal year 1964 Lectour, the Gallery's electronic guide system, was used by 59,472 visitors.

OTHER ACTIVITIES

Forty Sunday evening concerts were given during the fiscal year in the East Garden Court. These concerts were sponsored by the Calouste Gulbenkian Foundation, the J. I. Foundation, Inc., and the Andrew Mellon Endowment Fund of the National Gallery of Art. The National Gallery Orchestra, conducted by Richard Bales, played nine concerts at the Gallery during the season. One of these was made possible in part by a grant from the Music Performance Trust Fund of the American Recording Industry. The National Gallery Strings, conducted by Mr. Bales, furnished music during two exhibition openings. The concert on Sunday, October 20, 1963, was dedicated to United Nations Day. Six Sunday evenings, in May and June, were devoted to the Gallery's 21st American Music Festival. All concerts were broadcast in their entirety by radio station WGMS–AM and FM. Washington music critics continued their regular coverage of the concerts. During the intermission periods of the Sunday evening broadcasts, talks were delivered by members of the staff of the educational department on various art topics, and by Mr. Bales on the musical programs. Seven 1-hour TV concerts of the National Gallery Orchestra, with Mr. Bales conducting, were taped at the National Gallery and telecast on WTOP–TV. Mr. Bales and the National Gallery Orchestra received an award from the American Association of University Women for the outstanding cultural and educational contribution to the community through the television programs; and the Washington Chapter of the Academy of Television Arts and Sciences presented an award to WTOP–TV for the presentation of the National Gallery Orchestra's program of Italian Music and Art, citing it as the best cultural program of the year. The Baltimore Symphony Orchestra played Mr. Bales's arrangement of

"The Battle of Trenton"; and "The Blue and Gray Quadrille" by Mr. Bales was published in April 1964. Another of Mr. Bales's arrangements was published by the Gregorian Institute in a memorial edition to President Kennedy. The Institute also commissioned a hymn by Mr. Bales.

In response to requests, 18,261 copies of "An Invitation to the National Gallery of Art" and 712 information booklets were distributed to Congressmen and various organizations in the area.

Henry Beville, head of the photographic laboratory, and his assistants processed 24,314 items including negatives, prints, slides, color transparencies, and color separations.

A total of 153 permits were issued to copy works of art in the National Gallery, and 72 permits to photograph were issued.

AUDIT OF PRIVATE FUNDS OF THE GALLERY

An audit of the private funds of the Gallery will be made for the fiscal year ended June 30, 1964, by Price Waterhouse & Co., public accountants. A report of the audit will be forwarded to the Gallery.

Respectfully submitted.

HUNTINGTON CAIRNS, *Secretary.*

S. DILLON RIPLEY,
Secretary, Smithsonian Institution.

Report on the Canal Zone Biological Area

SIR: I have the honor to submit the following report on the operations of the Canal Zone Biological Area for the fiscal year ended June 30, 1964:

The Canal Zone Biological Area is responsible for maintaining Barro Colorado Island in Gatun Lake, Canal Zone, as a biological preserve. The area of the island is approximately 3,600 acres. It is almost completely covered by "tropical monsoon forest" (see tables 1 and 2 for the annual rainfall) and contains a rich fauna. It is one of the few places in the American tropics close to large centers of human population yet largely unaffected by recent human activities. Thus, it is particularly suitable and convenient for research on many aspects of tropical biology and the tropical environment.

TABLE 1.—*Annual rainfall, Barro Colorado Island, Canal Zone, 1925–63*

Year	Total inches	Station average	Year	Total inches	Station average
1925	104. 37	--------	1945	120. 42	109. 84
1926	118. 22	113. 56	1946	87. 38	108. 81
1927	116. 36	114. 68	1947	77. 92	107. 49
1928	101. 52	111. 35	1948	83. 16	106. 43
1929	87. 84	106. 56	1949	114. 86	106. 76
1930	76. 57	101. 51	1950	114. 51	107. 07
1931	123. 30	104. 69	1951	112. 72	107. 28
1932	113. 52	105. 76	1952	97. 68	106. 94
1933	101. 73	105. 32	1953	104. 97	106. 87
1934	122. 42	107. 04	1954	105. 68	106. 82
1935	143. 42	110. 35	1955	114. 42	107. 09
1936	93. 88	108. 98	1956	114. 05	107. 30
1937	124. 13	110. 12	1957	97. 97	106. 98
1938	117. 09	110. 62	1958	100. 20	106. 70
1939	115. 47	110. 94	1959	94. 88	106. 48
1940	86. 51	109. 43	1960	140. 07	107. 41
1941	91. 82	108. 41	1961	100. 21	106. 95
1942	111. 10	108. 55	1962	100. 52	107. 07
1943	120. 29	109. 20	1963	108. 94	107. 10
1944	111. 96	109. 30			

The Canal Zone Biological Area also has authority to use a small amount of land on the adjacent mainland, near Gamboa, Canal Zone. This mainland territory is covered by various types of second-growth vegetation and patches of forest which are more humid than the forest on Barro Colorado Island.

The bureau maintains a small but well-equipped laboratory on Barro Colorado Island, with attached library and living quarters, available for use by scientists and students from all over the world.

The scientific staff of the bureau conducts research on several groups of animals and plants on Barro Colorado itself, in adjacent regions of the Canal Zone and the Republic of Panama, and in other parts of Central and South America.

TABLE 2.—*Comparison of 1962 and 1963 rainfall, Barro Colorado Island*

[In inches]

Month	Total		Station average	Years of record	1963 excess or deficiency	Accumulated excess or deficiency
	1962	1963				
January	1. 86	7. 94	2. 29	38	+5. 65	+5. 65
February	. 67	3. 14	1. 36	38	+1. 78	+7. 43
March	. 08	1. 65	1. 22	38	+. 43	+7. 86
April	1. 84	6. 38	3. 52	39	+2. 86	+10. 72
May	12. 84	9. 08	10. 90	39	−1. 82	+8. 90
June	10. 13	5. 96	10. 69	39	−4. 73	+4. 17
July	13. 26	12. 83	11. 57	39	+1. 26	+5. 43
August	13. 21	18. 87	12. 60	39	+6. 27	+11. 70
September	13. 57	8. 06	10. 29	39	−2. 23	+9. 47
October	8. 43	10. 19	13. 89	39	−3. 70	+5. 77
November	13. 82	21. 60	17. 95	39	+3. 65	+9. 42
December	10. 81	3. 24	10. 82	39	−7. 58	+1. 84
Year	100. 52	108. 94	107. 10			+1. 84
Dry season	4. 45	19. 11	8. 39			+10. 72
Wet season	96. 07	89. 73	98. 71			−8. 88

RESEARCH ACTIVITIES

Ninety scientists and students visited Barro Colorado Island for at least several days and/or made use of bureau research facilities on the mainland last year. This represents a slight increase over the preceding year. The increase would have been larger had it not been for the reports of local civil disturbances which caused an appreciable number of scientists to cancel their proposed visits. Fortunately, the disturbances did not actually impede the day-to-day operations of the bureau.

Two scientists were added to the permanent staff last year: Dr. Robert L. Dressler and Dr. Neal G. Smith.

Dr. Dressler continued the studies of Orchidaceae which he has been pursuing for some years, supported by a National Science Foundation grant. In connection with this project, he made short field trips to Costa Rica and the Cayman Islands and studied specimens in the collection of the Missouri Botanical Garden. He also visited Miami to observe various species of orchids in cultivation there and to consult with Dr. C. H. Dodson, with whom he is collaborating in a study of pollination.

Dr. Smith began field work on the behavior and ecology of several groups of birds. He also visited Virginia Polytechnic Institute to secure information on histological and laparotomy techniques. studied collections of plant materials in the Gray Herbarium and the U.S. National Museum, studied the zoological collection of the U.S. National Museum, and visited the New York Zoological Society to obtain information on keeping and raising certain species of birds in captivity.

Dr. Moynihan continued studies of the signal patterns of platyrrhine monkeys and New World "nine-primaried" songbirds, and began a long-term investigation of geographical variation in social behavior among Andean birds, supported by a grant from the National Science Foundation. This last project necessitated field trips to Peru and Bolivia. Dr. Moynihan also attended the Eighth International Ethological Conference at The Hague in September 1963, studied collections in the U.S. National Museum and the American Museum of Natural History, and visited Harvard University for discussion of bioacoustical problems and techniques.

The following papers by current and former staff members of the Canal Zone Biological Area appeared in various publications:

Bennett, C. F., Jr. A phytophysiognomic reconnaissance of Barro Colorado Island, Canal Zone. Smithsonian Misc. Coll., vol. 145, No. 7, pp. 1–8. 1963.

Dressler, R. L. Index of orchid names–1962. Ann. Missouri Bot. Gard., vol. 50, pp. 53–54, 1963.

———. Another natural hybrid in *Epidendrum*. Amer. Orchid Soc. Bull., vol. 33, pp. 289–291, 1963.

Kaufmann, J. H., and Kaufmann, A. Some comments on the relationship between field and laboratory studies of behaviour, with special reference to Coatis. Animal Behaviour, vol. 11, pp. 464–469, 1963.

Moynihan, M. Inter-specific relations between some Andean birds. Ibis, vol. 105, pp. 327–339, 1963.

BUILDINGS AND EQUIPMENT

Maintenance activities on Barro Colorado Island continued as usual. Installation of the electric cable from the mainland to the island was delayed by various factors, but it is hoped that the work will be com-

pleted within the next few months. Remodeling of the laboratory, in anticipation of the air conditioning that will be installed after the cable is completed, has begun.

New cages for animals and a shade house for plants were constructed.

Five vehicles were obtained from U.S. Army surplus. They will be used for field research on the mainland. They are being reconditioned and remodeled for use as mobile field laboratories.

Expansion of the library has continued. In all probability, it is now the largest and best general biological library in the American tropics. It is frequently used by members of other scientific and educational organizations in the Canal Zone and the Republic of Panama, in addition to the scientists and students conducting research on Barro Colorado itself.

FINANCES

Trust funds for the maintenance of the island and its living facilities are obtained by collections from visitors and scientists, table subscriptions, and donations.

The following institutions continued their support of the laboratory through the payment of table subscriptions: Eastman Kodak Co., New York Zoological Society, and the Smithsonian Institution. Donations are also gratefully acknowledged from Dr. Eugene Eisenmann and C. M. Goethe.

PLANS

Discussions with the Organization of American States have been initiated in the hope of setting up a joint Smithsonian-OAS program of fellowships and assistantships, or grants-in-aid, to provide support for scientists and students, especially Latin Americans who do not have access to many other sources of support. It is hoped to continue expansion of the scientific staff and research activities of the bureau and to attract larger numbers of visiting scientists and students.

ACKNOWLEDGMENTS

The Canal Zone Biological Area can operate only with the excellent cooperation of the Canal Zone Government and the Panama Canal Company. Thanks are due especially to the Customs and Immigration officials; the Police Division; and the Division of Sanitation. Also deeply appreciated are the advice and assistance provided by the Gorgas Memorial Laboratory, the Inter-American Geodetic Survey, Dr. Nathan B. Gale of the Division of Veterinary Medicine, Dr.

W. John Smith of Harvard University, Dr. C. C. Soper of the Eastman Kodak Co., and R. A. Botzenmayer, Chief Engineer, Southern Command Network.

Respectfully submitted.

MARTIN H. MOYNIHAN, *Director.*

S. DILLON RIPLEY,
Secretary, Smithsonian Institution.

Report on the National Air Museum

Sir: I have the honor to submit the following report on the activities of the National Air Museum for the fiscal year ended June 30, 1964:

In July 1963 a Congressional appropriation of $511,000 was approved for the first year's planning funds for the new National Air Museum Building. The firm of Hellmuth, Obata & Kassabaum of St. Louis was employed as architects for the new building, with Mills, Petticord & Mills of Washington, D.C., as associate architects. During fiscal year 1964 the architects submitted a preliminary concept for the new building which received the approval of the National Air Museum staff and Advisory Board, members of the Smithsonian Board of Regents, the General Services Administration, the National Capital Planning Commission, and the National Commission of Fine Arts.

Legislation was introduced in Congress to change the name of the National Air Museum to the National Air and Space Museum, to increase the membership on the Advisory Board, and to authorize construction of the new building.

A generous gift to the Smithsonian Institution for the use of the National Air Museum was announced during the year—a grant from the Daniel and Florence Guggenheim Foundation of $250,000 over a 10-year period. The income from the grant is to be used for an annual lecture, a commemorative exhibit in the new building, and the employment of graduate students of history for research in the Museum's Historical Flight Research Center.

The beginning of a new exhibits department was established during the year in anticipation of the new building. James A. Mahoney was employed to head the unit.

A number of historically significant accessions were received by the Museum during the year. Among them were a Fleet Model 7 aircraft, from the Fleet Foundation; a Mark XV Norden Bombsight from John Wible; Helioplane No. 1, from the Helio Aircraft Corp.; a replica of *Oscar I*, world's first amateur satellite, from Project Oscar, Inc.; an RAF 1A aircraft engine of 1914, from United Aircraft Corp.; a Napier "Nomad" E, diesel compounded with turobjet aeronautical engine, from Napier Aero Engines, Ltd.; a DeHavilland 98

"Mosquito" light bomber of World War II vintage, from the Royal Air Force; the McDonnell XV-1 Convertoplane, from the McDonnell Aircraft Corp.; Inertial Guidance System from a Thor Launch Vehicle, from the U.S. Air Force; a collection of 419 medals and awards, all aviation related, from the American Institute of Aeronautics and Astronautics formerly the Institute of the Aeronautical Sciences; memorabilia of Lowell H. Smith, Commanding Officer of the First Round-the-World Flight, from Mrs. Lowell H. Smith; a Lincoln Standard J-1 aircraft of 1920, from the Kerr-McGee Oil Industries, Inc.; the first supercharged aircraft engines, from Vera C. Murray; oil portraits of Wilbur and Orville Wright, from the Flight Safety Foundation; a 1912 parachute used by "Tiny" Broadwick, from Mrs. G. T. Brown (Tiny Broadwick); Wiley Post's first pressure helmet, from the B. F. Goodrich Co.; oil portraits of Jacqueline Cochran and Charles E. Yeager by artist Chet Engle, from the Lockheed Aircraft Corp.; and memorabilia of Admiral Moffett from Rear Admiral Moffett, Jr.

An ever-growing information service to authors, researchers, historians, schools, Government agencies, students, and the public was an active function of the Museum during the year.

ADVISORY BOARD

The National Air Museum Advisory Board met in Washington on April 1, 1964, with all members present. Secretary S. Dillon Ripley was elected chairman. The Board approved the new building concept presented by the architects.

SPECIAL EVENTS

The first annual Edwin A. Link Lecture was presented on February 19, 1964, by Astronaut Alan B. Shepard, Jr. The annual Lester D. Gardner Lecture was presented on September 27, 1963, by Elmer A. Sperry, Jr. The Langley Medal was presented to Astronaut Alan B. Shepard, Jr., on May 5, 1964. Many distinguished visitors came to the Museum during the year to see the exhibit or to participate in special presentation and commemorative ceremonies.

The director attended several meetings of aviation, aerospace, and educational organizations and societies. He also visited a number of Air Force and Navy bases, National Aeronautics and Space Administration space centers, and contractors of these agencies in the aerospace flight program. He spoke frequently on these visits.

Paul E. Garber, head curator and historian, Louis S. Casey and Kenneth E. Newland, curators, and Walter Male, superintendent, represented the Museum at a number of aviation and aerospace meetings

during the year and spoke on the work of the Museum. Mr. Garber delivered 46 lectures.

IMPROVEMENT IN EXHIBITS

Continued experiments with display techniques in the Air and Space Building provided valuable experience in planning the exhibit for the new building.

REPAIR, PRESERVATION, AND RESTORATION

Storage, restoration, preservation, and the preparation of specimens for display in the new building were active and continuing functions at the Silver Hill, Md., activity.

ASSISTANCE TO GOVERNMENT DEPARTMENTS

Varied services, including information and counseling, were extended to the Federal Aviation Agency, National Aeronautics and Space Administration, the Department of Justice, the U.S. Navy, and the U.S. Air Force, during the year.

REFERENCE MATERIAL AND ACKNOWLEDGMENTS

The Museum's Historical Flight Research Center was greatly enriched during the year with valuable research materials. As space permits, these are being integrated into the files for the use of the Museum staff and other researchers.

The cooperation of the following persons and organizations in providing this material is sincerely appreciated and acknowledged:

Air Force Association, Earl Southee, Athens, Pa.: Two pages from a scrapbook—Bert Acosta and Emile Burgin and their airplane; Viola Gentry and Jack Ashcroft and the airplane *The Answer*.

Air Force Association, Richard Skinner, Washington, D.C.: Books, *Speaking of Space* by Richard M. Skinner and William Leavitt; and *The Wild Blue* by John F. Loosbrock and Richard M. Skinner.

Air Force Museum, Wright-Patterson AFB, Ohio: 8 boxes of documents—books, files, photos, and other data.

All-Women Transcontinental Air Race, Inc., Mrs. Kay A. Brick, Teterboro, N.J.: 2 copies "Official Program" 1961 race; 2 copies of the 1961 results; 5 photos, 1 of 1961 race winner, 2 of 1962 race winner, 2 of 1963 race winners.

American Antiquarian Society, Marcus A. McCorison, Worcester, Mass.: Scrapbook, "Ballooning in Springfield, Mass., 1908 and On" by Harlan T. Pierpont.

American Institute of Aeronautics and Astronautics, New York, N.Y.: Books, magazines, drawings, photos, and printed matter.

Army, Department of the, Paul J. Burnette, Washington, D.C.: Microfilm *Pegasus*, 1943–1957 (on 15 reels).

Autonetics (through James Carey), Anaheim, Calif.: Photographs (175) of the XN–1/XN–2.

BEARD, ROBERT L., Winfield, Kans.: 1 photo of the NC–4 at Ponta Del Gada, Azores; 1 photo of the NC–3 at Ponta Del Gada, Azores; 1 photo of the story of the NC transatlantic flight printed on a piece of Wong linen from the NC–3; 1 photo of the USS *Melville*, dated 8/22/18; 1 photo of Mr. Beard.

BELKNAPP, HUGH S., North Hollywood, Calif.: 3-view assembly drawing of the Ryan NYP.

BERLINER, HENRY A., ENGINEERING AND RESEARCH CENTER, Riverdale, Md.: 19 pamphlets; 15 books; 59 8- by 10-inch negatives; 3 4- by 5-inch glass negatives; 33 photographs—miscellaneous; report on the Probable Performance of the Berliner Helicopter in Climb; letters from MIT to Berliner.

BOBBETT, LT. COL. ROBERT L., USAF, Washington, D.C.: "The Evolution of Military Flight Pay," by Lt. Col. Robert L. Bobbett, USAF. 2 bound copies of typed papers, reproduced by a copy process, including illustrations, some furnished by the National Air Museum, and so acknowledged.

BRAZELTON, DAVID H., Bartonville, Ill.: Drawing of Curtis BT–1 aircraft.

BRISTOL SIDDELEY ENGINE, LTD., J. M. TOOGOOD, Leavesden, Hertfordshire, England: 1 copy of a 16 mm. color sound film showing Sir Geoffrey de Havilland with replica of his first engine; 1 12- by 17-inch color photograph; 1 11- by 14-inch matte finish black and white photograph; 1 8- by 10-inch glossy finish black and white photograph showing the de Havilland engine showroom at Leavesden.

CAPRONI DI TALIENDO, COUNTESS, Milan, Italy: 7 books and a set of postcards. Postcards-Senra Cozzar Dirocco: Books, *Let Us Kill the War; Senra Cozzar Dirocco; Sandrino Con I Caproni in Guerra; Ali Tricolori in Africa; La Centuria di Ferro* (3).

CASEY, L. S., Washington, D.C.: Book, *The Incomparable Sabreliner* by North American Aviation, Inc.

CATHCART, DONALD G., Hermosa Beach, Calif.: Photos; album; magazines; books; personal records; and papers.

CHAMBERLAIN, RALPH, Lincoln Park, Mich.: Book, *Dedication of the Wright Brothers' Home and Shop in Greenfield Village* by the Edison Institute.

CLARK, HENRY AUSTIN JR., Glen Cove, Long Island, N.Y.: Photographs; reports; newspaper clippings; magazines; books; records and personal papers of John J. Ide.

COAST GUARD, UNITED STATES, Elizabeth City, N.C.: 80 reels of microfilm on HSS/HUS helicopters.

CONTINENTAL AIRLINES, GEORGE R. COFFEY, Los Angeles, Calif.: 11 photographs; 11 "The Conair News"; 17 "The Golden Jet"; 3 "The Continental Eagle"; 1 "Everything's 'Go' on Continental"; Annual Report 1962; "Golden Jet Boeing 720B"; "Continental Airlines" a story of growth by Robert F. Six; timetable October 27, 1963; reprint from *Business Week;* "Airline Thrives of Split Personality"; two news releases.

EXPERIMENTAL AIRCRAFT ASSOCIATION AIR MUSEUM FOUNDATION, INC., Hales Corners, Wis.: Book, paper cover, *The Golden Age of Air Racing Pre 1940* by EAA; 13 EAA publications.

FEDERAL AVIATION AGENCY, W. H. WEEKS, Washington, D.C.: Reports on the President's Airport Commission, 1952; booklet, *A History of Propeller Manufacturers* by FAA.

FILIPPI, BERNARD P., Baltimore, Md.: 26 books on Lindbergh.

FISCHER, HAROLD A., Tonawanda, N.Y.: Drawings of the Fokker T–2 (3 plates); drawings of the Spandau machinegun (contract); drawing of the fuel, oil, and cooling systems—Fokker T–2.

Fliedner, C. S., Chevy Chase, Md.: Album received from the estate of Carlysle Fliedner, August 14, 1961, De Havilland H. 1 engine; contains 25 photographs and 12 transparencies.

Forster, McGuire & Co. Ltd., R. D. Forster, Montreal, Canada: Book, *The Magic of a Name* by Harold Nockolds.

Frantz, Harry W., Washington, D.C.: Book, *De Palos Al Plata* by Comandante Franco and Capitan Ruiz de Alda.

General Dynamics, Payne B. Johnson, San Diego, Calif.: Copy of black and white film taken at the presentation of the Mercury Control Center model.

Gill, Mabel E., Baltimore, Md.: 3 aviation scrapbooks; 3 auto scrapbooks; 14 auto photos; newspaper clippings; 2 membership cards—Baltimore Athletic Club 1907 and the Automobile Club of America; New Jersey automobile driver's license No. 27001.

Gleick Joseph T., Highland Park, Ill.: Curtiss Robertson Airplane Mfg. Co. organization chart; 12 negatives of Curtiss "*Robin*."

Greene, Frank L., Glasonbury, Conn.: Booklet, "History of the Grumman F4F 'Wildcat' " by Frank L. Greene.

Hardin, George W., Greeneville, Tenn.: Patents; photo and artist drawing of airship with 4-engine transport; photo of George W. Hardin; newspaper page; bill of authorization; report on hearings before the Committee on Military Affairs June 26, 1935 and March 20, 1936.

Hild, Fred C., Miami, Fla.: 1 scrapbook of newspaper clippings; 1 scrapbook of photographs; 1 ledger of the American Aeroplane Supply House; and biographical history.

Hildes-Seim, Erick, Fairfield, Conn.: Pamphlet, "The Air Arm of the Confederacy" by Joseph Jenkins Cornish III.

Hoover, Frederick A., La Jolla, Calif.: Newspaper clippings, the Chirp, June 1936; 30 photos, some on post cards; Aeromarine Airways leaflet "Ninety Minutes in Heaven," 1922; souvenir catalogue, Aeronautical Exposition, March 1–15, 1919; newspaper clippings (3)—"Museum Adds Prewar Biplane," *San Diego Union*, October 25, 1963; "Rep. Bob Wilson," *San Diego Union*, September–October 1963; "A Man With an Urge to Fly Like the Birds," Donald H. Gordon, *San Diego Union*, May 3, 1964.

Hopkins, Philip S., Washington, D.C.: 7 booklets; 3 books; and "Class Outline for Instructors," by P. S. Hopkins.

Information Agency, United States, Washington, D.C.: Tapes-Age of Flight, Nos. 1–4; Charles A. Macready, Parts I and II; B. Foulois Interview, Parts I and II; N. Halaby; Grover Loening—Pioneer Aviator; Conely Interview with Igor Sikorsky, Aviation Pioneer.

Istel, Jacques Andre, Orange, Mass.: 1 8- by 10-inch photograph of Jacques Istel, Lewis Sanborn, Nathan Pond, and William Jolly; 2 homologation documents dated April 17, 1962.

Jablonski, Edward, New York, N.Y.: AERONCA 1937 brochure: SOHIO roadmap guide to the 1939 National Air Race; Eastern Air Lines timetable May 17, 1937; United Air Lines timetable March 1, 1937; "Learning to Fly"; Symbols and Notes for Department of Commerce Sectional Airways Maps; the Fairchild "24."

Jahn, Mrs. E., White Plains, N.Y.: 1 scrapbook compiled by James V. Martin; 140 photographs of various J. V. Martin aeroplanes, stabilizers, wheels, and retractable chassis.

Kegel, Henry J., Los Angeles, Calif.: Book, *Modern Aircraft* by Page.

Kerley, Robert V., Ethyl Corporation, Detroit, Mich.: Air Corps technical report "American and Foreign Military and Commercial Aircraft"; Booklet,

"A New Wasp, Series 'H' "; 3 photos with captions of Boeing 314 "Clipper"; 1 photo Boeing 307 "Substratosphere" with caption and fact sheet; 24 cover sheets "Technical Data Digest" by U.S. Army Air Corps; 1 booklet titled "Origin of A–N Performance Number System"; 1 handbook titled "Research on Aviation Spark Plug Problems"; 1 pamphlet titled "The 17.6 Engine, Its Design, Development and Applications" by A. E. Felt and Robert V. Kerley.

LANCASTER, MRS. HUGH K., Mill Valley, Calif.: 2 sets of 11 photos each of Martin 130 "China Clipper."

LECH, ANDREW F., Glendora, Calif.: Drawing of "Ryan NYP Spirit of St. Louis" (3 plates).

MACAULAY, MRS. T. C., Severna Park, Md.: Album, photos, and letters of T. C. Macaulay.

MEANS, JAMES H., Boston, Mass.: Original patents awarded and held by James Means. Patent drawings and reports; correspondence; photographs; newspaper clippings; and biographical material.

MEYER, OTTO, Augsburg, West Germany: Pamphlet, "On the History of Air Transportation."

MILLING, MARGARET, Washington, D.C.: 16 military certificates and statements; 375 photographs of various sizes of Milling, other aviators and planes; 1 14- by 11-inch photo of General Milling in uniform; 4 8- by 10-inch negatives; approximately 35 to 40 pieces of news articles; four pieces of correspondence.

MOLLER, JOSEPH A., Tucson, Ariz.: Book, *The Story of the 390th Bombardment Group (H)*.

MYLES, MRS. EUGENIE LOUISE, Edmonton, Alberta, Canada: Book, *Airborne from Edmonton* by Eugenie Louise Myles.

NASH, MISS CAROLYN, Washington, D.C.: 1 Norwegian pamphlet on the Amundsen-Ellsworth Expedition, 1925; 1 post card showing the memorial stone in Ny-Aalesund of the Amundsen-Ellsworth Expedition, 1925; 1 fragment of balloon cloth or parachute cloth.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, PAUL HANEY, Houston, Tex.: 30 reels of motion-picture films.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, JAMES J. MODARELLI, Cleveland, Ohio: Aircraft engine overhaul instructions handbooks for J35–A–17D, J35–A–27A, J35–A–29A USAF, U35–A–29A USN, and for J–33–A–33, J–33–A–33A USAF; photographs, 8 by 10, black and white of the four pilots who were honored as recipients of the Robert J. Collier Trophy for the year 1961—Joseph A. Walker, CDR Forrest S. Petersen, Major Robert M. White, and A. Scott Crossfield.

NAVY, DEPARTMENT OF THE, AVIATION SAFETY CENTER, Norfolk, Va.: "Approach," bound Vol. 8, July 1962–June 1963.

NEWLAND, KENNETH E., Alexandria, Va.: Book, *Squadrons of the Royal Air Force* by Maj. F. A. de V. Robertson, Lt. Comdr. C. N. Colson, and Flying Officer W. A. Cook; book, *The Incomparable Sabreliner* by North American Aviation, Inc.

NYE, WILLIS L., Hayward, Calif.: Drawing of Curtiss S–3.

OLMSTEAD, GERHART, Little Rock, Ark.: 364 photos and negatives; 10 10- by 13-inch brown envelopes containing papers and reports; C.M.O. notebook; certificate from Patent Office: notebook-laws and minutes of C.M.O. Physical Laboratory, Inc.; scrapbook-calculations; scrapbook, Flying Test of Olmsted Propellers.

Page, George A. Jr., Reynoldsburg, Ohio: 2 photograph albums, Volume I containing 234 prints of the CW–20, H 75B, P–40–171, XP–46, O–52, XP–60 XP–62; Volume II containing 128 prints of the HF5–6, P–40–100, XP60–16, P–47–4, B–24–1, G–205–1.

Parsons, Rear Admiral E. C., Osprey, Fla.: Book, *I Flew with the Lafayette Escadrille* by E. C. Parsons.

Pratt, John Brooks, Charlotte Amalie, Virgin Islands: 8- by 10-inch photographs and negatives of the "Round the World Cruisers" being serviced (wheels for pontoons) on the Hoogly River on June 27, 1924.

Russell, Frank F., New York, N.Y.: Colored aviation prints of 14 aviation scenes; 4 French aviator portraits of World War I by H. Farre.

Sampson, Philip Squire, Arlington, Va.: Newspaper clippings, 1 full page of Lindbergh (head and shoulders); 2 full pages of some of the items sent to the Missouri Historical Society, St. Louis; 6 pertaining to Harry W. Lyon, navigator of the transpacific airplane *Southern Cross.*

Shamburger, Miss Page, Aberdeen, N.C.: Book, 1st ed., *Tracks Across the Sky* by Page Shamburger.

Soaring Society of America, Los Angeles, Calif.: 49 back issues of *Soaring Magazine.*

Solomon, Samuel J., Silver Spring, Md.: Two booklets, "Survival" by Airlines War Training Institute; and "Pilgrim's Process" by Air Transport Command, U.S. Army Air Forces.

Stone, Victor L., Reseda, Calif.: Parts catalog of Robertson Aircraft Co. and "Catalog A" 1928 parts list of Curtiss OX5–OXX6 and Hispano-Suiza.

Stratton, Samuel Wesley, Family of (through Wesley S. Hobbs), Tulsa, Okla.: 2 photograph scrapbooks, 1 on the "Langley," a Handley Page bomber built by the Standard Aircraft Corporation, 1918; 1 titled "Sezione Fotografica di Aviazione per la R. Marine" (Italian aviation photographs of World War I).

Tetzlaff, Delavan, Wis.: Magnetic recording tape, 7-inch size, of interview with Jesse C. Bradazon, an Early Bird.

Tracy, Daniel, Lakewood, Ohio: 2-view drawing of Wright "J" long-hulled flying boat, 1915, 3 sheets.

Tuscarawas County Aviation, Inc., New Philadelphia, Ohio: John H. Glenn's original primary flight file.

Waterman, Edward C., Miami, Fla.: 25 8- by 10-inch prints of early personages of the 1914–1918 period at North Island.

Watertown Daily Times, John B. Johnson, Watertown, N.Y.: 2 photos, article on the Pepin airship; photo of airship *Inocrain.*

Weather Bureau, United States, Washington, D.C.: Project Tiros data, 12 black and white 8- by 10-inch photos; 1 map of world showing route of Tiros, 12 by 30; 1 color 8- by 10-inch print; 3 mosaics.

Weiman, Ken, South Miami, Fla.: 9 aviation photographs including 4 Douglas World Cruisers, 1 Boeing SP–12A, and 1 Douglas BT–2B.

Whittier, Robert J., South Duxbury, Mass.: Drawings from Curtiss Engineering Corporation, eighth size, Curtiss Oriole.

Wilber, Paul F., Rochester, N.Y.: 16 4½- by 6-inch photographs of Curtiss copy type airplane, Curtiss flying boat, Benoist airplanes, Maximotor engines, and Tony Jannus with Benoist; 4 pages of xerox copy of newspaper articles of Paul Wilber; 1 3-view blueprint of a standard Curtiss Type Biplane 28′4″; 1 blueprint of wood details for 28′4″ Curtiss Type Biplane.

WILLIAMSON, MRS. MARGARET S., Cleveland, Tenn.: Single issue of Aerial Age, February 2, 1920.

YAGER, MR. & MRS. FRANK R., Anaheim, Calif.: *Saga of the U.S. Air Mail Service* by the Air Mail Pioneers, Inc.; poem, "The Westbound Mail" by Phil Braniff; *A Brief History of the Air Mail Service of the U.S. Post Office Department* (*May 15, 1918–August 31, 1927*) by Edward A. Keogh.

ACCESSIONS

Additions to the National Aeronautical and Space Collections, received and recorded during the fiscal year 1964, totaled 559 specimens in 71 separate accessions, as listed below. Those from Government departments are entered as transfers, unless otherwise indicated; others were received as gifts or loans.

AIR FORCE, DEPARTMENT OF THE, ANDREWS AFB, Md.: Holley automatic cutaway variable Venturi carburetor (ca. 1941) (N.A.M. 1451); VANDENBURG AFB, Calif.: Inertial guidance system from a THOR launch vehicle (N.A.M. 1442); CAMERON STATION, Va.: Redstone rocket engine recovered after the June 11, 1958, ballistic missile trajectory flight from Canaveral (N.A.M. 1473).

B. F. GOODRICH CO., Akron, Ohio: Pressure helmet used by Wiley Post with his first two experimental space suits (N.A.M. 1467).

BARCAS, VICTOR, Washington, D.C.: Autographed original menu for luncheon given for C. A. Lindbergh in Paris, autographed by Lindbergh, Glenn, Carpenter, Gargarin, and Titov (N.A.M. 1448).

BELL AIRCRAFT CO., Buffalo, N.Y.: Bell model 47D–1 single 2-blade rotor helicopter with directional rotor at aft end of machine (N.A.M. 1430).

BROWN, MRS. G. T., Henderson, N.C.: Very early back-pack parachute used by "Tiny" Broadwick for exhibition jumps from airplanes in 1912 (N.A.M. 1466).

CROM, CURTISS G., Springfield, Va.: Unusual dress uniforms and officer's saber which belonged to donor's late father, colonel in USAF (N.A.M. 1462).

DIENES, NICHOLAS S., Fort Belvoir, Va.: Fragment, airship *Hindenburg* girder (N.A.M. 1458).

DOOLITTLE, JAMES H., SPACE TECHNOLOGY LABORATORIES, Redondo Beach, Calif.: Medal of the Ordre Souveraine de Chypre (No. PA 400) given to the donor (N.A.M. 1480).

DOUGLAS AIRCRAFT CO., Washington, D.C.: Model THOR IRBM space launch vehicle, 1:22 size (N.A.M. 1469).

EASTERN AIR LINES, INC., New York, N.Y.: 2 framed study sketches by Dean Cornell made for murals in EAL building (N.A.M. 1441).

EMERSON, EARL A., Arlington, Va.: World War II USAF winter flying suit, worn on antisubmarine patrol by Lt. James D. Emerson, son of the donor (N.A.M. 1468).

FLEET FOUNDATION, San Diego, Calif.: Fleet model 7 aircraft powered by 160 hp. Kinner R–56 engine (N.A.M. 1417).

FLIGHT SAFETY FOUNDATION, New York, N.Y.: 2 oil portraits of the Wright Brothers, painted by Efrem Melik (N.A.M. 1465).

GARBER, PAUL E., Washington, D.C.: La Crocciera Atlantica Gold Medal (N.A.M. 1446).

GENERAL DYNAMICS, San Diego, Calif.: 4-foot square scale model of Mercury Control Center at Cape Canaveral (N.A.M. 1431).

GILL, MRS. MABEL E., Baltimore, Md.: Silver tray-trophy awarded to H. W. Gill (N.A.M. 1484)

GODDARD, MRS. ROBERT H., Worcester, Mass.: 2 bronze reproductions of gold medal awarded to Dr. Goddard by Congress in 1959 (N.A.M. 1427).

GRAYSON, LT. COMDR. K. B., Forest Hills, N.Y.: Mark 1A bombsight of World War I period (N.A.M. 1419).

HARTWICK, HERBERT D., Cayucos, Calif.: Model of Fokker D–VII, 1:16 size (N.A.M. 1482).

HELIO AIRCRAFT CORPORATION, Norwood, Mass.: Helioplane No. 1, first of a series of controllable STOL aircraft (N.A.M. 1425).

HOLLOWOOD, CHARLES L., Pittsburgh, Pa.: Model of Stinson, Jr., aircraft (N.A.M. 1436).

AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS, New York, N.Y.: 4 personal watches of the Wright Brothers (N.A.M. 1450); collection of 419 medals and awards, all related to aviation (N.A.M. 1452).

JONES, MRS. LOUIS C., Cooperstown, N.Y.: Flag and barometer used by Charles F. Durant (N.A.M. 1479).

KERLEY, ROBERT V., ETHYL CORPORATION, Detroit, Mich.: Engine components and awards and medals belonging to S. D. Heron, engine and fuel expert (N.A.M. 1471); slide rule and drafting set belonging to S. D. Heron (N.A.M. 1432).

KERR-MCGEE OIL INDUSTRIES, INC., Oklahoma City, Okla.: Aircraft, Lincoln Standard J–1, Reg. No. 1375, Ser. No. 177, 1920, powered by Hispano-Suiza Model A–3, Ser. No. 5407 (N.A.M. 1455).

KIRKHAM, CHARLES B., Montgomery, N.Y.: Kirkham air-cooled engine built in 1929, 6-cylinder, horizontally opposed (N.A.M. 1416).

LEITE, RONALD F., Alexandria, Va.: Lang propeller (English) designed for the 400-hp. Liberty engine, 1918 (N.A.M. 1478).

LOCKHEED AIRCRAFT CORPORATION, Burbank, Calif.: Model of Lockheed F–104, 1:48 size (N.A.M. 1457); oil portraits of "Jackie" Cochran and "Chuck" Yaeger (N.A.M. 1472); Model of Lockheed TF–104G (N.A.M. 1459).

MARTIN AIRCRAFT CO., Baltimore, Md.: Model of Martin B–10 bomber (N.A.M. 1439).

MCDONNELL AIRCRAFT CORPORATION, St. Louis, Mo.: McDonnell XV–1 Convertoplane (N.A.M. 1435).

MIKESH, MAJOR ROBERT C., San Franciso, Calif.: Model of Douglas DST (first of DC–3 series) in American Airlines livery, Neg. No. NC 14988 on rudder and wings (N.A.M. 1456); series of 8 B–17 models depicting the development of the B–17 series (N.A.M. 1440).

MILLING, MRS. T. DEWITT, Washington, D.C.: Military aviator wings awarded to 2nd Lt. T. D. Milling, October 6, 1913 (N.A.M. 1449).

MOFFETT, REAR ADM., JR., Virginia Beach, Va.: Memorabilia of Admiral Moffett—Adm. Moffett's magnetic compass; plaster bust of Adm. Moffett; rear admiral flag; rivet press and gold rivet used on *Shenandoah* (N.A.M. 1483).

MURRAY, MISS VERA C., Washington, D.C.: 2 Murray engines, 70-hp., 2-cycle, 6-cylinder; 30-hp., 2-cycle, 6-cylinder rotary engine; tools (N.A.M. 1464).

NAPIER AERO ENGINES, LTD., London, England: Napier "Nomad" E, diesel compounded with turbojet aeronautical engine (N.A.M. 1429).

NATIONAL AERONAUTIC ASSOCIATION, Washington, D.C.: Plaque of William Thaw and 4 Gordon Bennett Trophy plaques (N.A.M. 1474).

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, Washington, D.C.: Duplicate of NASA Distinguished Service Medal awarded to Alan B. Shepard, Jr.

(N.A.M. 1444); LANGLEY RESEARCH CENTER, Langley Field, Va.: 3 scale models—Ryan Flex-Wing; Supersonic Furled Flex-Wing; and wind tunnel item—Flex-Wing (N.A.M. 1476).

NAVY, DEPARTMENT OF THE, Williamsburg, Va.: Hispano-Suiza engine model E (N.A.M. 1486); NAVAL ACADEMY, Annapolis, Md.: Models of Douglas TBD–1, Grumman J2F–1, Vought SB2U–1 scout bomber (N.A.M. 1460); MARINE CORPS, Quantico, Va.: Japanese double-barreled aircraft machinegun and Spandau German aircraft machinegun (N.A.M. 1453); MARINE CORPS SCHOOL, Quantico, Va.: 9 aircraft machineguns and cannons with spare barrel assembly (N.A.M. 1470).

PAN AMERICAN WORLD AIRWAYS, New York, N.Y.: Model of Douglas DC–7F showing cargo handling equipment (N.A.M. 1461).

PROJECT OSCAR, INC., Sunnyvale, Calif.: Full-size replica of *OSCAR I*, world's first amateur satellite, plus two separate components of the radio signalling device (N.A.M. 1426).

PYLE, JAMES T., Washington, D.C.: Early flying suit, 1930's (N.A.M. 1463).

RAY, DR. E. L., through BURKE M. RAY, Washington, D.C.: 2 silver spoons commemorating 1935 flight of Thor Solberg from Norway to United States (N.A.M. 1424).

REPUBLIC AVIATION CORPORATION, Farmingdale, Long Island, N.Y.: Model of Republic FH–105 USAF fighter (N.A.M. 1445).

ROYAL AIR FORCE, United Kingdom: DeHavilland 98 *Mosquito* light bomber of World War II vintage (N.A.M. 1434).

SMILEY, DR. C. H., Providence, R.I.: Cent carried by donor on flight to photograph eclipse of 7/20/63 (N.A.M. 1423).

SMITH, J. C., Massillon, Ohio: Scale model of Verville CA–3 aircraft (N.A.M. 1443).

SMITH, MRS. LOWELL H., Tucson, Ariz.: Memorabilia including personal items, awards, scrapbooks, photographs, etc., belonging to Lowell H. Smith, the commanding officer of the first Round-the-World Flight (N.A.M. 1454).

SMITHSONIAN INSTITUTION, EXHIBITS DIVISION, Washington, D.C.: Model of Boeing B–17G World War II bomber (N.A.M. 1422); model of Wright Brothers 1899 kite (N.A.M. 1438).

SPACE TECHNOLOGY LABORATORIES, Redondo Beach, Calif.: 3 full-scale models of research satellites, *Pioneer I*, *Pioneer V*, and *Explorer VI* (N.A.M. 1475).

SPENCER, PERCIVAL H., Hawthorne, Calif.: Working model of *Motorized Bird*, an ornithopter (N.A.M. 1437).

STANLEY AVIATION CORPORATION, Denver, Colo.: B–58 supersonic ejection seat and capsule (N.A.M. 1433).

SWAIN, JOHN, Arlington, Va.: Pilot's leather helmet, late 20's (N.A.M. 1420).

THIOKOL CHEMICAL CORPORATION, Ogden, Utah: Cutaway of M–58 Falcon rocket motor (N.A.M. 1421); REACTION MOTORS DIVISION, Danville, N.J.: Rocket jump-belt by Thiokol (N.A.M. 1485).

TRACY, DANIEL E., Cleveland, Ohio: Scale model of Macchi–39 Schneider trophy-winning seaplane, 1929 (N.A.M. 1447).

UNITED AIRCRAFT CORPORATION, Hartford, Conn.: RAF 1A aircraft engine of 1914 (N.A.M. 1428).

WIBLE, JOHN, Andrews AFB, Md.: Mark XV Norden bombsight (N.A.M. 1418).

WILBURN, GENE, N., Chevy Chase, Md.: Unidentified wind tunnel test model (N.A.M. 1477).

ZIEMER, MAJOR H. A., Pine Bluff, Ark.: Collection of 225 civilian and military buttons (N.A.M. 1481).

Philip S. Hopkins, director of the National Air Museum since 1958, announced his retirement as of August 1, 1964. S. Paul Johnston has been selected as the new director. He will take office on September 1, 1964.

Respectfully submitted.

PHILIP S. HOPKINS, *Director.*

S. DILLON RIPLEY,
Secretary, Smithsonian Institution.

Report on the John F. Kennedy Center for the Performing Arts

SIR: I have the honor to submit, on behalf of the Board of Trustees, a status and financial report on the John F. Kennedy Center for the Performing Arts (formerly the National Cultural Center) for the period July 1, 1963, through June 30, 1964.

ORGANIZATION

Public Law 85–874, September 2, 1958, established the National Cultural Center as a bureau of the Smithsonian Institution. The initial legislation was amended by Public Law 86–297, September 21, 1959. Public Law 88–100 was enacted on August 19, 1963. This amended the original law by extending the term for fund-raising from 5 to 8 years and increased the maximum number of public members of the Board of Trustees from 15 to 30.

With the tragic death of President Kennedy, a spontaneous reaction spread throughout the country to dedicate the National Cultural Center as his sole memorial in the Nation's Capital. In December 1963 President Lyndon Johnson sent the proposal to Congress, and hearings were subsequently held before a joint session of the House and Senate Public Works Committee. I had the honor of testifying before these hearings. The Bill passed the House and the Senate with full bipartisan support, and on January 23, 1964, President Johnson signed it into law.

Provisions of the legislation.—The National Cultural Center was renamed the John F. Kennedy Center for the Performing Arts. Under the provisions of this Act, authorization was given for the appropriation of $15.5 million to match funds raised by the public. In addition, the Center's trustees were empowered to issue revenue bonds to the Treasury payable from revenues accruing to the Board, up to a sum of $15.4 million to cover the cost of a 3-level parking facility for approximately 1,600 cars. This unit will also form the substructure of the building. (The National Capital Planning Commission was granted a further appropriation of $2.175 million for the purchase of land within and without the designated site and for relocation payments.)

The Center's testimony was given before the House and Senate Appropriations Committees, and final action was taken when both houses of Congress agreed to the amended Appropriations Bill on June 29. (It was signed by President Johnson on July 7.) Under the terms of this legislation (P.L. 88–356) Congress provided "such amounts which in the aggregate will equal gifts, bequests, and devises of money, securities, and other property, received by the Board for the benefit of the John F. Kennedy Center for the Performing Arts prior to July 1, 1965, and available or used for expenditures directly incident to the planning, contracting, and construction of the Center: Provided, That the total amount appropriated by this paragraph shall not exceed $15,500,000."

The John F. Kennedy Center Act made no change in the composition of the Board of Trustees, the officers, the Advisory Committee on the Arts, or the concept and charter of the Center.

Mrs. Lyndon B. Johnson agreed to serve as honorary cochairman with Mrs. John F. Kennedy and Mrs. Dwight D. Eisenhower.

At the present time the Board of Trustees and elected officers of the Center are as follows:

PROGRESS DURING 1963–1964

All the Center's fund-raising committees continued, on an increased scale, the activities initiated in the previous year:

(1) *President's Business Committee.*—Ernest R. Breech, formerly chairman, Ford Motor Co., maintained his effective leadership of this

committee which has, to date, raised more than $2.7 million. In October 1963 President Kennedy was host at a luncheon in the White House to members of the Committee, as well as other top business leaders from all parts of the country. (As a direct result of this occasion, industrial contributions amounting to approximately $1 million were received within a short period of time thereafter.)

(2) *Service band recordings.*—During the year a second royalty payment was received from RCA Victor Records covering the sale of the four military service band albums issued by RCA on behalf of the Center, for a further 6-month period, September 1963 through February 1964. This royalty payment amounted to $60,197.81, bringing the total proceeds from the sale of the records to $120,039.02.

(3) "*Creative America*," published by Ridge Press, went on nationwide sale in February 1963. A percentage of the proceeds from the sale of the book is being paid to the Center. The book traces the full circle of artistic creation and contains a foreword by President Kennedy, original articles by General Eisenhower, President Truman, James Baldwin, Mark Van Doren, John Ciardi, among others, as well as more than 90 pages of color pictures by the staff of Magnum, one of the world's outstanding associations of photographers.

(4) *Gifts of foreign governments.*—During the year the Center received substantial gifts from two foreign governments. In July 1963 President Kennedy announced that the Italian Government through President Segni had offered a contribution of all the marble required in the building of the Center. In October the Prime Minister of Ireland, Mr. Sean Lemass, offered the gift of a Waterford chandelier to hang in the Center's symphony hall. Several other foreign governments have also shown an interest in making donations to the Center.

(5) In October 1963 the Rockefeller Foundation made an unconditional grant to the Center of $1 million, and in December a gift of $500,000 came from the Old Dominion Foundation.

(6) *Special Gifts Committee.*—Plans have been completed for the formation of a national Special Gifts Committee to seek substantial contributions to the Center from sources other than business and industry. A contract has been negotiated with the firm of Bowen & Gurin, New York City, to coordinate the fund-raising efforts of this committee.

(7) *Mrs. Kennedy's Christmas cards.*—During the summer of 1963 Mrs. Kennedy graciously offered to design two Christmas cards to be sold for the benefit of the Center. The cards were published and distributed by Hallmark Cards and enjoyed a very considerable sale.

Publicity relating to the cards was nationwide and the Center received approximately $26,000 from their sale.

(8) *Announcement of Center's programs.*—During the course of the year, two programs were announced in which the Center was a joint sponsor.

a. In October, President Kennedy announced the formation of a national company of the Metropolitan, to be presented by the Metropolitan Opera and the Center. The purpose of this company, which will begin its first tour of some 35–37 cities in the fall of 1965, is to provide training and experience for young American singers, and to bring the best in live opera to cities throughout the country where little or none has previously existed.

b. Plans were also announced for a National University Theatre Festival to be held in Washington, D.C., during a 3-week period in the spring of 1965. Jointly sponsored by the Center, the American Educational Theatre Association, and the American National Theatre and Academy, the Festival is inviting the participation of the many college and university theatre groups in the country. Organized at the outset on a regional basis, it is expected that some 10 or 12 college groups will be selected to present their outstanding productions to audiences in the Capital.

ADMINISTRATIVE CHANGES

With the pending eligibility for Government funds, both through our borrowing authority and from Congressional appropriations, the Center has been in close consultation with the offices of the Secretary of the Treasury, the Comptroller General, the Bureau of the Budget, and the Smithsonian Institution. Upon their recommendation and with the unanimous approval of the Board of Trustees, an Administrative Officer, Philip J. Mullin, was appointed who will be responsible for the administrative and fiscal management of the Center.

GENERAL SERVICES ADMINISTRATION

Arrangements were made whereby the Public Buildings Service of the General Services Administration will serve as the Center's agent for design and construction, and a contract to this effect is about to be signed. Standard GSA procedures will be followed, including the award of contracts on the basis of competitive bids.

MEMORIAL COMMITTEE

In accordance with the provisions of the John F. Kennedy Center Act, a Memorial Committee under the chairmanship of K. LeMoyne Billings has been appointed. This committee will originate, assemble, and review proposals, and make recommendations, for a suitable memorial to President Kennedy to be placed within the Center itself. The trustees will then make their recommendation to the Congress and to the Regents of the Smithsonian as the law provides. Members of this committee are:

Senator William Fulbright
Senator Leverett Saltonstall
Congressman Torbert H. Macdonald
Mrs. Stephen Smith, President Kennedy's sister
Mrs. Albert D. Lasker, a Trustee
Edward Durell Stone, the Center's architect
S. Dillon Ripley, Secretary of the Smithsonian Institution
Theodore C. Sorensen, who served as Special Counsel to President Kennedy
(Roger L. Stevens will serve as an *ex officio* member)

FINE ARTS ACCESSIONS COMMITTEE

Because of an increasing number of objects of art that are being offered to the Center, it has been found necessary to appoint a Trustees' Fine Arts Accessions Committee to determine acceptance or refusal of such gifts. The Committee will, in turn, appoint a subcommittee containing representatives of the architect, the General Services Administration, the National Collection of Fine Arts, the National Gallery of Art, and of two leading non-Federal galleries in Washington. Members of the Accessions Committee are:

S. Dillon Ripley, Secretary of the Smithsonian Institution, *Chairman*
Mrs. Albert D. Lasker, Mrs. Jouett F. Shouse, and Senator J. William Fulbright

ARCHITECTURAL PLANNING

Following some controversy in the press on the size and site of the Center, all questions relating to these matters were finally and satisfactorily resolved on June 4 when the National Capital Planning Commission, the central planning agency for the Federal and District of Columbia Governments, voted approval of the site, access points, height, bulk, and profile of the building, as well as of the dimensions of the three halls. This action left the way clear for final planning of the construction of the Center.

Preliminary architectural plans have now been completed and the architect and his staff are starting on the working drawings. Site borings have been completed. It is hoped that construction on the substructure of the building will begin in the summer of 1965, with completion of the Center within 30 months. A ground-breaking ceremony is now being planned.

FUTURE PROSPECTS

The events of the past fiscal year have put us well within sight of our objective to create in the Nation's Capital a national center for the performing arts, as well as an appropriate and living memorial to President Kennedy.

To comply technically with the matching provisions of the Appropriations Act $2 million more is needed before June 30, 1965. In addition, it is the intention to raise $3 million to provide working capital and a reserve against increased building costs.

Respectfully submitted.

ROGER L. STEVENS,
Chairman.

S. DILLON RIPLEY,
Secretary, Smithsonian Institution.

The Center's Financial Report for the period July 1, 1963, through June 30, 1964, follows:

AUDIT

July 25, 1964
Washington, D.C.

TO THE BOARD OF TRUSTEES OF THE
JOHN F. KENNEDY CENTER FOR THE PERFORMING ARTS
Washington, D.C.

Gentlemen:

We have examined the books and records of the JOHN F. KENNEDY CENTER FOR THE PERFORMING ARTS for the period July 1, 1963, through June 30, 1964, and submit our report herewith as follows:

Exhibit A—Balance Sheet as of June 30, 1964.
Exhibit B—Statement of Income, Expenses and Fund Balance for the Year July 1, 1963, through June 30, 1064.
Exhibit B-1 Statement of Expenses for the Year July 1, 1963, through June 30, 1964.
Schedule 1—Schedule of Time Deposits, Savings Account and Treasury Bills.

Our examination was made in accordance with generally accepted auditing standards and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion the accompanying report presents fairly the financial position of the JOHN F. KENNEDY CENTER FOR THE PERFORMING ARTS at June 30, 1964, and the results of its operation for the period then ended in conformity with generally accepted accounting principles.

Respectfully submitted.

(S) JOHN J. ADDABBO,
Certified Public Accountant.

EXHIBIT A

BALANCE SHEET

June 30, 1964

ASSETS

Current assets:			
Cash in banks:			
General account	$269, 151. 29		
Reserve account	50, 428. 49		
Time deposits and savings accounts	2, 584, 753. 97		
		$2, 904, 333. 75	
Treasury bills		1, 160, 887. 00	
Stock and property received		12, 500. 00	
Petty cash		400. 00	
Deposit with airlines		425. 00	
			$4, 078, 545. 75
Pledges receivable:			
National General Account		5, 091, 627. 98	
National Tangible Property		1, 168, 000. 00	
National Seat Reserve Account		67, 444. 00	
President's Business Committee		822, 134. 67	
Washington Area Building Fund—General		294, 228. 46	
Washington Area Building Fund—Reserve		346, 400. 00	
Washington Area Seat Reserve Account		103, 638. 48	
Washington Area Federal Employee Drive		3, 286. 50	
Washington Area Federal Employee Drive—Seat Endowment		1, 660. 00	
Washington Area Tangible Property		35, 000. 00	
School Children's Reserve Fund		185. 00	
J. F. Kennedy Memorial Fund		1, 000. 00	
Israeli Benefit		20, 190. 00	
			7, 954, 795. 09
Fixed assets:			
Cost of land—advanced to National Capital Planning Commission		146, 000. 00	
Construction costs—architect and design costs		507, 498. 25	
Furniture and equipment—book value		5, 962. 62	
			659, 460. 87
Other assets:			
Deferred charges—Creative America			56, 425. 00
Total assets			$12, 749, 226. 71

LIABILITIES AND NET WORTH

Liabilities:			
Payroll taxes withheld			$1, 177. 54
Net worth:			
Pledges receivable		$7, 954, 795. 09	
Fund balance—June 30, 1964		4, 793, 254. 08	
			12, 748, 049, 17
Total liabilities and net worth			$12, 749, 226. 71

NOTE: Pledges receivable; national general account includes Ford Foundation grant of $5,000,000.00 on a two-to-one matching basis of nongovernmental funds.

EXHIBIT B

STATEMENT OF INCOME, EXPENSES, AND FUND BALANCE

Year ended June 30, 1964

Contributions and pledges paid in:		
General accounts:		
National General Account	$1,757,966.84	
President's Business Committee	1,292,577.28	
Fine Arts Gifts Committee	5,000.00	
Closed Circuit Telecast	7,281.82	
Washington Area Building Fund	261,823.98	
Washington Area Federal Employee Drive	118,035.50	
Austrian Embassy Benefit	13,322.53	
Peter Pan Benefit	13,845.73	
Israeli Benefit	26,942.22	
Interest Income	28,932.98	
Total general accounts		$3,525,728.88
Reserve accounts:		
National Reserve Account	------------	
National Seat Reserve Account	$105,325.00	
Washington Area Building Fund	207,983.54	
Washington Area Seat Reserve Account	133,673.57	
Washington Area Endowment Fund	----------	
Washington Area Federal Employee Drive—Seat Endowment	23,149.43	
School Children's Reserve Fund	20,497.86	
John F. Kennedy Memorial Fund	15,235.51	
Total reserve accounts		505,864.91
Total income		4,031,593.79
Deduct expenses—exhibit B-1		557,576.47
Excess of receipts over expenses		3,474,017.32
Fund balance—beginning of year		1,319,236.76
Fund balance—June 30, 1964		$4,793,254.08

EXHIBIT B–1

STATEMENT OF EXPENSES

Year ended June 30, 1964

Salaries—major	$63, 671. 48
Salaries—D.C	22, 735. 48
Salaries—Fine Arts	---------
Extra help	8, 869. 89
Depreciation—furniture and equipment	716. 51
Equipment—rental and repairs	1, 162. 32
Meetings	747. 18
Office supplies and postage	7, 918. 15
D.C. area expenses—general	5, 950. 47
Fine Arts Gifts Committee	--------
Seat endowment	580. 43
Printing and publicity	3, 382. 82
Promotion	35, 188. 33
Publications	2, 370. 25
Telephone and telegraph	12, 820. 70
Travel and maintenance	17, 029. 96
Taxes—payroll and civil service	2, 792. 95
Unclassified	1, 388. 39
Accounting	4, 005. 00
Insurance	3, 624. 93
Interest	--------
Fund-raising fees	50, 750. 00
Legal fees	21, 900. 00
Miscellaneous fees	---------
President's Business Committee	113, 898. 98
Federal Employee Drive	2, 012. 50
Closed Circuit Telecast	152, 561. 80
Peter Pan Benefit	5, 125. 82
Austrian Embassy Benefit	2, 062. 89
Israeli Benefit	1, 197. 37
College Drama Festival	5, 000. 00
Band Recording	1, 055. 30
Sousa Memorial Fund	1, 914. 08
N.Y. World's Fair Inaugural Ball	5, 142. 49
Total expenses	$557, 576. 47

NOTE: Expenses include capitalized expenditures charged off in the amount of $150,000.00.

SCHEDULE 1

SCHEDULE OF TIME DEPOSITS, SAVINGS ACCOUNT, AND TREASURY BILLS
June 30, 1964

Depositary	Date deposited	Maturity date	Interest rate per annum	Amount deposited
American Security & Trust Co.	2/17/64	8/17/64	3¾%	$18,000.00
Washington, D.C.	2/17/64	8/17/64	3¾%	225,000.00
	2/21/64	8/21/64	3¾%	40,000.00
	3/2/64	9/2/64	3¾%	100,000.00
Perpetual Bldg. Assoc.	11/15/63	11/15/64	4%	200,000.00
Washington, D.C.				
Manufacturers Hanover Trust Co.,	11/18/63	11/18/64	3⅞%	200,000.00
New York, N.Y.				
Irving Trust Co.	11/18/63	11/18/64	3¾%	200,000.00
New York, N.Y.				
National Bank of Detroit	11/18/63	11/18/64	4%	200,000.00
Detroit, Mich.	3/25/64	3/25/65	4%	150,000.00
Morgan Guaranty Trust Co.	11/18/63	11/18/64	3¾%	200,000.00
New York, N.Y.				
Manufacturers Nat'l Bank of Detroit.	11/18/63	11/18/64	3⅞%	200,000.00
Detroit, Mich.				
Home Savings & Loan Assn.	11/18/63	11/18/64	4.85%	300,000.00
Beverly Hills, Calif.				
Savings Account				
Interest credited Jan. 1964.				1,753.97
Chase Manhattan Bank	12/31/63	1/4/65	3⅞%	100,000.00
New York, N.Y.	1/10/64	1/11/65	4%	150,000.00
Schroder Trust Co.	2/18/64	8/18/64	3⅞%	100,000.00
New York, N.Y.				
Chemical Bank N.Y. Trust Co.	2/26/64	8/26/64	3⅞%	100,000.00
New York, N.Y.	2/28/64	8/28/64	3⅞%	100,000.00
Treasury bills	#1446905	11/30/64		963,300.00
	#5706009	9/3/64		99,121.00
	#5706108	11/19/64		98,466.00
Total				3,745,640.97

Report on the National Portrait Gallery

SIR: I have the honor to submit the following report on the activities of the National Portrait Gallery for the fiscal year ended June 30, 1964:

The Act of April 27, 1962 (Public Law 87–443) provided for the establishment of the National Portrait Gallery as a bureau of the Smithsonian Institution. As described in the act, the purpose of the Gallery is to "function as a free public museum for the exhibition and study of portraiture and statuary depicting men and women who have made significant contributions to the history, development, and culture of the people of the United States and of the artists who created such portraiture and statuary."

The Smithsonian Board of Regents at its January 1963 meeting took two important actions:

(I) *Approved the functions of the National Portrait Gallery Commission:*

The National Portrait Gallery Commission shall have the primary functions of promoting the administration, development, and utilization of the National Portrait Gallery, including the acquisition of material of high quality representing men and women who have made significant contributions to the history, development, and culture of the people of the United States and of the artists who created such portraiture and statuary.

In this connection, the Commission shall:

(1) Advise the Secretary on the appointment and compensation of the Director of the National Portrait Gallery, with the consent of the Board of Regents.

(2) With the assistance of the Director of the National Portrait Gallery, prepare recommended criteria for the acquisition of portraits, statuary, or other items authorized under the Act of April 27, 1962, for presentation to the Board of Regents for adoption.

(3) Develop proposed rules and regulations for the operation of the National Portrait Gallery.

(4) Act as a "board of recommendation" for items presented to the National Portrait Gallery, or items proposed to be purchased for the National Portrait Gallery, subject to final approval by the Board of Regents.

(5) Adopt an official seal which shall be officially noticed.

(6) Be responsible for reviewing the proposed program for the development of the National Portrait Gallery, developed by the Director of that Gallery.

(7) As a group and as individual members, be responsible for encouraging gifts, within the criteria approved by the Board of Regents, of funds, portraits, statuary, and other items which would enhance the value and significance of this important Gallery to the people of the United States in commemorating the men

and women who have made significant contributions to the history, development, and culture of the United States.

(8) Submit to the Board of Regents an annual report of the operations of the Gallery.

(II) *Determined the number and tenure of members of the National Portrait Galley Commission:*

The National Portrait Gallery Commission, created by Public Law 87–443, April 27, 1962, shall be composed of the Chief Justice of the United States, the Secretary of the Smithsonian Institution, and the Director of the National Gallery of Art, as members *ex-officio*; and eight appointive members, chosen as provided in this section, who shall be citizens of the United States.

The appointive members of the Commission first taking office shall be chosen by the Board and shall have terms expiring two each on July 1 of 1965, 1966, 1967, and 1968, as designated by the Board. Successors shall be chosen by the Board from nominees presented by the Commission and the Secretary of the Smithsonian Institution, and shall have a term expiring six years from the date of the expiration of the term for which the predecessor was chosen, except that a successor chosen to fill a vacancy occurring prior to the expiration of such term shall be chosen only for the remainder of such term. Notwithstanding the expiration of the term of office provided by this section for any member of the Commission, such member shall continue to serve as such until his successor has been appointed and has qualified.

The Commission may function notwithstanding vacancies, and six members shall constitute a quorum for the transaction of business.

The Chancellor of the Board of Regents, the Honorable Earl Warren, announced the membership of the National Portrait Gallery Commission on June 21, 1963. (The members are listed in the 1963 report.)

The significant first meeting of the National Portrait Gallery Commission was held on October 21, 1963. Dr. John Nicholas Brown, Regent of the Smithsonian Institution, was elected chairman. The basic functions of the National Portrait Gallery were discussed and a subcommittee was appointed to develop criteria for admission to the National Portrait Gallery.

A discussion of the qualifications for Director and Associate Director resulted in an agreement that the two types of skills needed at the top of the organization were:

(1) A highly capable museum or art gallery director who is a good administrator, and

(2) A historian who knows American history and could be a leading research man.

Dr. Brown designated the following terms of Commission members:

	Term ending July 1 of year indicated below
Mrs. Bowen and Dr. Boyd	1965
Dr. Brown and Dr. Deschler	1966
Mr. Finley and Dr. Lewis	1967
Dr. Shryock and Colonel Todd	1968

At the second meeting of the Commission on December 20, 1963, it was reported that bids for the remodeling of the F Street Building were 35 percent higher than the funds available. Therefore, the bids had to be rejected, with the understanding that the Smithsonian would work with the architect and the General Services Administration to reduce the scope of the remodeling to bring the cost within the funds available.

At this meeting the twofold objectives of the National Portrait Gallery were reaffirmed: (1) exhibition of portraits and statuary of men and women who have made contributions to the history, development, and culture of the United States, and (2) the provision of necessary bibliographical, biographical, and historical materials for a study center.

The chairman announced that he had appointed the following subcommittee on criteria: Mr. Lewis (chairman), Mrs. Bowen, and Mr. Boyd. The Commission recommended and the Regents approved the appointment of Charles Nagel to be Director of the National Portrait Gallery, and this was announced on March 3, 1964. Mr. Nagel will enter on duty July 1, 1964. Mr. Nagel has been director of the City Art Museum of St. Louis, Mo., and prior to that he was director of the Brooklyn Museum.

At the third meeting of the Commission on February 26, there was a detailed discussion of the proposed rules for selection to the permanent collections to the National Portrait Gallery. A subcommittee was appointed to make recommendations on the proposed library, research, and publication program. The members were Dr. Shryock, Mr. Lewis, and Dr. Boyd.

At the fourth meeting of the Commission on May 1, 1964, the proposed library, research, and publication program were discussed. The rules for selection to the permanent collection were approved for submission to the Board of Regents.

In their May 1964 meeting, the Regents approved the rules for selection to the permanent collection, as follows:

The purpose of the National Portrait Gallery is to collect and exhibit portraits and sculpture of persons who have made significant contributions to the history, development, and culture of the United States of America from its earliest period of discovery to the present and, as integral to this purpose, to establish a research center in American iconography and biography.

I. The Gallery hopes to acquire the best likenesses available, originals from life if possible, replicas or copies if necessary. The initial selection shall be made by the National Portrait Gallery Commission acting upon the recommendations of the Director and the Committee on acquisitions. The recommendations shall be circulated to the Commission before the meeting at which the selections are to be made. Approval of such recommendations shall be by a majority of two-thirds of the Commission. Proxy votes shall be admissible for this purpose.

II. No likeness of any person who has been dead less than ten years shall be exhibited in the permanent collection with the exception of the President of the United States and his wife.

III. Temporary exhibitions dealing with specific fields of interest may be held from time to time. Special provision shall be made in the Gallery for the display of the likenesses of the President of the United States and his wife, the Vice President, the Speaker of the House of Representatives, the Chief Justice of the United States, the Secretary of State, the Associate Justices of the Supreme Court, the President's Cabinet, and Members of the Congress.

IV. The Research Center shall include archival material necessary for iconographical, biographical, and historical study.

Respectfully submitted.

THEODORE W. TAYLOR, *Assistant to the Secretary.*

S. DILLON RIPLEY,
Secretary, Smithsonian Institution.

Report on the Library

Sir: I have the honor to submit the following report on the activities of the Smithsonian library for the fiscal year ended June 30, 1964:

ACQUISITIONS

The acquisitions section received 120,008 publications during the year. This included 4,498 purchased items and 1,284 journal subscriptions. The rest were received by exchange or as gifts. Arrangements were made with 81 new organizations for the exchange of new publications.

Some of the outstanding gifts presented to the library by interested donors are:

Brasher, Rex. Birds and trees of North America. 4 vols. New York, 1961–1962, from Rowman and Littlefield, Inc., New York, N.Y.

A collection of 19th century travel literature (479 brochures, maps, folders, guides), from Mr. and Mrs. E. P. Morris, Southampton, Pa.

Griffiths, John Willis. Treatise on marine and naval architecture. 1849, from Mrs. Myrtie Hall, Landers, Calif.

Kienbusch, Carl Otto von. The Kretzschmar von Kienbusch collection of armor and arms. Princeton, 1963, from C. O. von Kienbusch, New York, N.Y.

Leupold, Jacob. Theatrum pontificale . . . 1726, and 11 additional volumes on architecture, art and geography, published between 1738 and 1871, from Mrs. Carolyn Edwards, Glen Echo, Md.

Marconi's wireless telegraphic code, 1907, and four additional volumes on electricity and communications, from Laurence E. Whittemore, Short Hills, N.J.

Mearns, Louis de Zerega. Mammals and birds; a collection of biological publications . . . 1897–1903, from Mrs. C. L. Coleman, Troy, N.Y.

Piranesi, Giovanni Battista, 1720–1778. Antiquariorum Regiae Societatis Londinensis Campus Martius Antiquae Urbis. 1762 (Opere . . . v. 10), and a volume of engravings, from Mrs. C. E. Bullowa, Philadelphia, Pa.

22 books on the physical sciences published 1891–1935, from the Estate of William W. Coblentz, Brightwood, Va.

55 volumes, including works on art and on science, from the Embassy of the Federal Republic of Germany, Washington, D.C.

400 volumes of historical materials on science and technology, including a set of Allgemeine Deutsche Biographie, 1875–1912, from the U.S. Naval Observatory Library.

A total of 71,094 pieces of duplicate and extraneous materials were forwarded to other libraries. The Library of Congress received 60,977 items; the National Library of Medicine, 2,245; and the

National Agricultural Library, 1,406 pieces. A combined total of 191,102 pieces of material was handled by the section.

CATALOGING AND BINDING

The catalog section cataloged 10,574 volumes, recataloged 205 items, transferred 750 publications, discarded 138 volumes, recorded 35,042 serials in the Serial Record, and filed 34,718 cards into the card catalogs. In addition, 478 trade catalogs were added to the collection.

The binding unit prepared 5,175 books and journals for binding by a commercial binder. The hand-binding staff preserved 1,859 publications which were fragile or too valuable to be sent outside the Institution for repair.

REFERENCE AND CIRCULATION

The reference librarians answered 38,453 requests for specific types of information, replied to 3,459 pieces of correspondence, circulated 40,409 books and journals, and cleared the loan records on 30,277 volumes. No record is kept of the circulation and use of the publications assigned to the divisional libraries where they circulate freely within the division. Publications borrowed from other libraries, chiefly the Library of Congress, numbered 4,777, and 1,309 volumes were lent. Xerox copies of many articles were supplied in lieu of loaning the old, fragile, or heavily used publications. The reading and reference facilities were used by 29,146 persons.

BRANCH LIBRARIES

The branch library for the Museum of History and Technology answered 12,496 reference questions, circulated 13,588 books and journals, and added 478 trade catalogs to the collection. Persons using the reading and reference areas numbered 5,149. This library was moved from the Arts and Industries Building to the new Museum of History and Technology Building in February.

The Bureau of American Ethnology branch library answered 697 reference questions, circulated 924 books and journals, and provided assistance to 774 patrons. Mrs. Carol Jopling, librarian, resigned in October.

The branch library for the Smithsonian Astrophysical Observatory, Cambridge, Mass., answered 3,135 reference requests, circulated 2,045 books and journals, and provided library services for 7,577 users.

The department of entomology branch library answered 996 reference requests, circulated 985 books and journals, and 1,571 patrons used the library facilities.

PROGRAMS AND FACILITIES

Features that contribute to the usefulness of the new library for the Museum of History and Technology are its central location, reading and browsing areas, new furniture and equipment, workspace for the staff, and good natural and artificial lighting.

Funds were allotted by the library to the different departments and bureaus for the selection of library materials. Keysort record cards are in process for use in ordering periodical subscriptions and continuations.

Through participation in the National Science Foundation Public Law 480 program for translation of Russian text materials, the Smithsonian Institution received English translations of 36 scientific monographs pertinent to Smithsonian interests. Copies of these translations have been distributed to American libraries.

STAFF ACTIVITIES

The staff continued to attend special courses and seminars for growth and development. Participation was active in professional organizations and in attendance at the annual conferences for the Special Libraries Association and American Library Association. Jack Goodwin was elected chairman of the museum division of the Special Libraries Association.

Mrs. Parepa Jackson, exchange librarian, in the acquisitions section, retired in March. Mrs. Frances Jones visited the libraries for the Smithsonian Astrophysical Observatory and Harvard University, Cambridge, Mass., and the libraries for the Vermont State Historical Society, Montpelier, and the Boston Museum of Fine Arts.

SUMMARIZED STATISTICS

TABLE 1.—*Accessions to the Library in fiscal year 1964*

Library	Volumes	Total recorded volumes, 1964
Smithsonian central library including the Museum of Natural History	4, 544	361, 848
Museum of History and Technology	3, 530	
Astrophysical Observatory (SI)	1	13, 408
Smithsonian Astrophysical Observatory, Cambridge, Mass	561	2, 903
Radiation and Organisms	77	2, 244
Bureau of American Ethnology	257	40, 151
National Air Museum	184	1, 327
National Collection of Fine Arts	179	14, 698
National Zoological Park	31	4, 333
National Portrait Gallery	73	73
Total	9, 437	440, 985
Trade catalogs	478	4, 154

Unbound volumes of periodicals and reprints and separates from serial publications, of which there are many thousands, have not been included in the above totals.

Exchanges:	
New exchanges arranged	81
Specially requested publications received	1, 064
Cataloging:	
Volumes cataloged	11, 489
Catalog cards filed	34, 718
Serials: Number of serials recorded	35, 042
Circulation: Loans of books and periodicals	40, 409
Binding and repair:	
Volumes sent to the bindery	5, 175
Volumes repaired in the library	1, 859

Respectfully submitted.

Ruth E. Blanchard, *Librarian.*

S. Dillon Ripley,
Secretary, Smithsonian Institution.

Report on Publications and Information

Sir: I have the honor to submit the following report on the publications of the Smithsonian Institution and its branches and on other informational activities for the year ended June 30, 1964:

The editorial and publications division, the publishing arm of the Institution, maintains a four-part program. One includes the editing, designing, and publishing of books and reports on explorations and research by staff members and collaborators of the Institution in the fields of science, history, and art, and the production of publications of a more popular nature, such as museum guidebooks, informational leaflets, and art catalogs. The second is the control and distribution of these publications. The third deals with the day-to-day dissemination of information concerning the Smithsonian to the press and the inquiring public; the chief of the division serves as public-relations officer of the Institution. And the fourth covers the printing of materials of a current and emergency nature, such as museum labels and invitations and announcements of Smithsonian events, in a branch of the Government Printing Office which is housed at the Institution for that purpose.

PUBLICATIONS PROGRAM

Ninety-five publications appeared under the Smithsonian imprint during the past year in its various series, as listed below. These publications are issued partly from federally appropriated funds (Smithsonian Reports and publications of the National Museum, the Bureau of American Ethnology, the National Air Museum, and the Astrophysical Observatory) and partly from private endowment funds (Smithsonian Miscellaneous Collections, publications of the Freer Gallery of Art, and some special publications). The Institution also publishes under the auspices of the Freer Gallery of Art the series Ars Orientalis, which appears under the joint imprint of the University of Michigan and the Smithsonian Institution. In addition, the Smithsonian publishes for sale to visitors guidebooks, information pamphlets, postcards, folders, and popular publications on scientific and historical subjects related to its important exhibits and collections.

Smithsonian Miscellaneous Collections

In this series, under the immediate editorship of Mrs. Nancy Link Powars, the following papers were issued:

Volume 145

No. 5. Tertiary echinoids from the Caloosahatchee and Tamiami formations of Florida, by Porter M. Kier. 64 pp. 18 pls. (Publ. 4543.) August 2, 1963. ($2.)

No. 6 Additions to records of birds known from the Republic of Panama, by Alexander Wetmore. 11 pp. (Publ. 4523.) December 16, 1963. (50 cents.)

No. 7. A phytophysiognomic reconnaissance of Barro Colorado Island, Canal Zone, by Charles F. Bennett, Jr. 8 pp. 1 map. (Publ. 4527.) December 20, 1963. (50 cents.)

Volume 146

No. 2. A contribution toward an encyclopedia of insect anatomy, by Robert E. Snodgrass. 48 pp. (Publ. 4544.) July 12, 1963. ($1.)

No. 3. Solar variation and weather, by C. G. Abbot. 68 pp. 4 pls. (Publ. 4545.) October 18, 1963. ($1.)

Volume 147

No. 1. The architecture of Pueblo Bonito, by Neil M. Judd. 349 pp. 81 pls. (Publ. 4524.) June 30, 1964. ($6.)

Smithsonian Annual Reports

REPORT FOR 1962

The complete volume of the Annual Report of the Board of Regents for 1962 was received from the printer on September 26, 1963.

Annual Report of the Board of Regents of the Smithsonian Institution showing the operations, expenditures, and condition of the Institution for the year ended June 30, 1962. x +610 pp., illustr. (Publ. 4518.)

The general appendix contained the following papers (Publ. 4546–4566):

Aircraft propulsion: A review of the evolution of aircraft powerplants, by C. Fayette Taylor.

Rocket propulsion, by Ralph S. Cooper.

The early history of radar, by R. M. Page.

Modern glass, by S. Donald Stookey.

The great earthquakes of May 1960 in Chile, by Pierre Saint-Armand.

The rim of the reef, by E. Yale Dawson.

What's happening to water? By Charles J. Robinove.

The opening of the Arctic Ocean, by James T. Strong.

The place of genetics in modern biology, by George W. Beadle.

The shark that hibernates, by L. Harrison Matthews.

Man in a world of insects, by Dwight M. DeLong.

Tropical fruit-fly menace, by L. D. Christenson.

The soil as a habitat for life, by Sir John Russell.

The evolution of the echinoderms, by E. Barraclough Fell.

Mangroves: Trees that make land, by William M. Stephens.

The history and relationships of the world's cottons, by Sir Joseph Hutchinson.

Some mysteries of life and existence, by R. E. Snodgrass.

Civilization and the landscape, by Sylvia Crowe.

How many people have ever lived on earth? By Annabelle Desmond.

Bows and arrows: A chapter in the evolution of archery in America, by Paul E. Klopsteg.

Scientific methods in the examination and conservation of antiquities, by A. E. A. Werner.

REPORT FOR 1963

The report of the Secretary, which will form part of the 1963 Annual Report of the Board of Regents, was issued January 23, 1964.

Report of the Secretary and financial report of the Executive Committee of the Board of Regents for the year ended June 30, 1963. xii + 275 pp. 15 pls. (Publ. 4525.)

SPECIAL PUBLICATIONS

Preliminary field guide to the mackerel- and tuna-like fishes of the Indian Ocean (Scombridae), by Bruce B. Collette and Robert H. Gibbs, Jr. 48 pp. 10 pls. (Publ. 4567.) August 9, 1963.

The gown of Mrs. John F. Kennedy. [Supplement to "The Dresses of the First Ladies of the White House," by Margaret W. Brown, published by the Smithsonian Institution in 1952. (Publ. 4060.)] November 26, 1963. (50 cents.)

The Star-Spangled Banner. 16 pp. + postcard. (Publ. 4529.) January 1964. (15 cents.)

Brief guide to the museums in the Washington area. 39 pp. illus. (Publ. 4588.) March 6, 1964. (25 cents.)

Dedication of the Museum of History and Technology of the Smithsonian Institution. 26 pp. (Publ. 4531.) March 24, 1964. (50 cents.)

The exhibits speak, by Sophy Burnham. (With a section on "Birds of the World," by Linda S. Gordon.) 49 pp. (Publ. 4536.) June 5, 1964. (50 cents.)

REPRINTS

Smithsonian meteorological tables. Prepared by Robert J. List. Sixth revised edition. Second reprint. (Publ. 4014.) July 19, 1963. ($5.)

The First Ladies Hall. 8 pp. (Publ. 4212.) (Two runs: July 31, 1963; April 27, 1964.) (25 cents.)

The Smithsonian Institution. 50 pp. (Publ. 4145.) August 1, 1963. (50 cents.)

The fishes of North and Middle America, by David Starr Jordan and Barton Warren Evermann. (Bulletin 47 of the United States National Museum.) 4 vols. lx+3,313 pp. illustr. (Reprinted for the Smithsonian Institution by T.F.H. Publications.) May 18, 1964. ($25.)

First book of grasses: the structure of grasses explained for the beginner, by Agnes Chase. 127 pp. (Publ. 4351.) Third edition. June 3, 1964. ($3.)

UNITED STATES NATIONAL MUSEUM PUBLICATIONS

The editorial work of the National Museum continued during the year under the immediate direction of John S. Lea, assistant chief of the division. The following publications were issued:

REPORT

The United States National Museum annual report for the year ended June 30, 1963. Pp. vii+226, illustr., January 23, 1964.

BULLETINS

226. Checklist of the birds of Thailand, by Herbert G. Deignan. Pp. x+263, 1 fig. December 31, 1963.

227. Part 1. Marine polychaete worms of the New England region: 1. Families Aphroditidae through Trochochaetidae, by Marian H. Pettibone. Pp. v+356, 83 figs., November 5, 1963.
234. Cephalopods of the Philippine Islands, by Gilbert L. Voss. Pp. v+180, 4 pls., 36 figs., August 27, 1963.
236. Free-living Copepoda from Ifaluk Atoll in the Caroline Islands with notes on related species, Willem Vervoort. Pp. ix+431, 151 figs., June 30, 1964.
244. Bagworm moths of the Western Hemisphere (Lepidoptera: Psychidae), by Donald R. Davis. Pp. v+233, 12 maps, 385 figs., June 1, 1964.

CONTRIBUTIONS FROM THE NATIONAL HERBARIUM

Volume 32

Part 4. The genus *Dussia* (Leguminosae), by Velva E. Rudd. Pp. iii+247–277, 11 figs., November 4, 1963.

Volume 34

Part 2. The woods and flora of the Florida Keys: Capparaceae, by William L. Stern. George K. Brizicky, and Francisco N. Tamolang. Pp. 25–43, 7 pls., November 4, 1963.

Volume 36

Part 3. The lichen family Graphidaceae in Mexico, by Michael Wirth and Mason E. Hale, Jr. Pp. 63–119, 82 figs., December 6, 1963.

Volume 38

Part 1. A revision of *Trichantha* (Gesneriaceae), by Conrad V. Morton. Pp. 1–27, October 9, 1963.

PROCEEDINGS

Volume 115

No. 3476. Additional information on the morphology of an embryo whale shark, by J. A. F. Garrick. Pp. 1–7, 4 pls., February 28, 1964.
No. 3477. Notes on new and old species of Alticinae (Coleoptera) from the West Indies, by Doris H. Blake. Pp. 9–29, 25 figs., February 28, 1964.
No. 3478. Asteroidea of the *Blue Dolphin* expeditions to Labrador, by E. H. Grainger. Pp. 31–46, 4 figs., February 28, 1964.
No. 3479. Moths of the genus *Rhabdatomis* Dyar (Arctiidae: Lithosiinae), by William D. Field. Pp. 47–60, 6 pls. (33 figs.), February 28, 1964.
No. 3480. Neotropical Microlepidoptera, III. Restriction of *Gonionota melobaphes* Walsingham with descriptions of new species (Lepidoptera: Oecophoridae), by J. F. Gates Clarke. Pp. 61–83, 3 pls. (1 color), 7 figs., March 17, 1964.
No. 3481. Chironomid midges of California. II. Tanypodinae, Podonominae, and Diamesinae, by James E. Sublette. Pp. 85–135, 7 figs., February 28, 1964.
No. 3482. Caligoid copepods (Crustacea) of the Hawaiian Islands: parasitic on fishes of the family Acanthuridae, by Alan G. Lewis. Pp. 137–244, 24 figs., February 28, 1964.
No. 3483. Notes on Aradidae in the U.S. National Museum. III. Subfamily Mezirinae (Hemiptera), by Nicholas A. Kormilev. Pp. 245–258, 7 figs., February 28, 1964.
No. 3484. A generic revision of the leafhopper subfamily Neocoelidiinae (Homoptera: Cicadellidae), by James P. Kramer. Pp. 259–287, 114 figs., March 17, 1964.

No. 3485. A review of the North American moths of the family Walshiidae (Lepidoptera: Gelechioidea), by Ronald W. Hodges. Pp. 289–329, 66 figs., March 17, 1964.

No. 3486. American species of the lacebug genus *Acalypta* (Hemiptera: Tingidae), by Carl J. Drake and John D. Lattin. Pp. 331–345, 15 pls., December 31, 1963.

No. 3487. The caligid copepod genus *Dentigryps* (Crustacea: Caligoida), by Alan G. Lewis. Pp. 347–380, 13 figs., March 17, 1964.

No. 3488. A new Brazilian moth of the genus *Gonioterma* with notes on related species (Lepidoptera: Stenomidae), by W. Donald Duckworth. Pp. 381–389, 3 figs., March 17, 1964.

No. 3489. Seven new amphipods from the west coast of North America with notes on some unusual species, by Clarence R. Shoemaker. Pp. 391–429, 15 figs., March 17, 1964.

No. 3490. Shrimps of the genus *Betaeus* on the Pacific coast of North America with descriptions of three new species, by Josephine F. L. Hart. Pp. 431–466, 2 pls., 80 figs., February 28, 1964.

No. 3491. Notes on some nearctic Psychomyiidae with special reference to their larvae (Trichoptera), by Oliver S. Flint, Jr. Pp. 467–481, 5 figs., February 28, 1964.

Bureau of American Ethnology Publications

The editorial work of the Bureau continued under the immediate direction of Mrs. Eloise B. Edelen. The following publications were issued during the year:

REPORT

Eightieth Annual Report of the Bureau of American Ethnology, 1962–1963, ii+34 pp., 2 pls. 1964.

BULLETINS

Bulletin 178. Index to Bulletins 1–100 of the Bureau of American Ethnology, with index to Contributions to North American Ethnology, Introductions, and Miscellaneous Publications, by Biren Bonnerjea. vi+726 pp. 1963.

Bulletin 186. Anthropological Papers, Nos. 63–67. iv+310 pp., 60 pls., 35 figs., 2 maps. 1963.

- No. 63. Tarquí, an early site in Manabí Province, Ecuador, by Matthew W. and Marion Stirling.
- No. 64. Blackfoot Indian pipes and pipemaking, by John C. Ewers.
- No. 65. The Warihio Indians of Sonora-Chihuahua: An ethnographic survey, by Howard Scott Gentry.
- No. 66. The Yaqui deer dance: A study in cultural change, by Carleton Stafford Wilder.
- No. 67. Chippewa mat-weaving techniques, by Karen Daniels Petersen.

Bulletin 187. Iroquois music and dance: Ceremonial arts of two Seneca Longhouses, by Gertrude P. Kurath. xvi+268 pp., 3 pls., 164 figs. 1964.

Bulletin 189. River Basin Surveys Papers, Nos. 33–38, Frank H. H. Roberts, Jr., editor. xiv+406 pp., 58 pls., 66 figs., 13 maps. 1964.

- No. 33. The Paul Brave site (32S14), Oahe Reservoir area, North Dakota, by W. Raymond Wood and Alan R. Woolworth.
- No. 34. The Demery site (39CO1), Oahe Reservoir area, South Dakota, by Alan R. Woolworth and W. Raymond Wood.
- No. 35. Archeological investigations at the Hosterman site (39PO7), Oahe Reservoir area, Potter County, South Dakota, 1956, by Carl F. Miller.

No. 36. Archeological investigations at the Hickey Brothers site (39LM4), Big Bend Reservoir, Lyman County, South Dakota, by Warren W. Caldwell, Lee G. Madison, and Bernard Golden.

No. 37. The Good Soldier site (39LM238), Big Bend Reservoir, Lyman County, South Dakota, by Robert W. Neuman.

No. 38. Archeological investigations in the Toronto Reservoir area, Kansas, by James H. Howard.

Bulletin 190. An ethnography of the Huron Indians, 1615–1649, by Elisabeth Tooker. iv+184 pp. 1964.

Astrophysical Observatory Publications

The year's publications in the series Smithsonian Contributions to Astrophysics are as follows:

Volume 4

No. 5. A criterion for the mode of ablation in stone meteors, by Allan F. Cook. Pp. ii + 131–136. July 3, 1963.

No. 6. The microscopic properties of meteorites, by Gustav Tschermak. Pp. ix +137–239. June 4, 1964.

Volume 6

Research in space science, by Fred L. Whipple, et al. 242 pp. August 30, 1963.

Volume 8

No. 1. Accurate drag determinations for eight artificial satellites; atmospheric densities and temperatures, by Luigi G. Jacchia and Jack Slowey. Pp. 1–99. September 12, 1963.

No. 2. The relative positions of sunspots and flares, by John G. Wolbach. Pp. 101–118. July 12, 1963.

No. 3. Type IV solar radio bursts, geomagnetic storms, and polar cap absorption (PCA) events. Pp. 119–131. October 3, 1963.

National Collection of Fine Arts Publications

The following catalogs were issued by the Smithsonian Institution Traveling Exhibition Service during the year:

Turner watercolors. 23 pp. +80 illus. (Publ. 4519.) 1963.

Indian miniatures. 67 pp. (Publ. 4520.) 1963.

Eighteenth-century Venetian drawings. 58 pp. + 118 illus. 1963.

7000 years of Iranian art. 184 pp. +157 illus. (Publ. 4535.) 1964.

Freer Gallery of Art Publications

Ars Orientalis, vol. V. (Publ. 4540.) 354 pp. illus. December 30, 1963. ($31.)

Oriental Studies No. 6. Armenian illustrated manuscripts in the Freer Gallery of Art, by Sirarpie Der Nersessian. (Publ. 4516.) 145 pp. + 108 pls. December 30, 1963. ($10.)

American Historical Association Reports

The annual reports of the American Historical Association are transmitted by the Association to the Secretary of the Smithsonian Institution and are by him communicated to Congress, as provided in the act of incorporation of the Association. The following reports were issued during the year:

Annual report of the American Historical Association for 1962. Vol. 1. Proceedings. November 1963.

Writings in American history, 1955. Vol. 2 of Annual Report of the American Historical Association for 1957. September 25, 1963.

Writings in American history, 1956. Vol. 2 of Annual Report of the American Historical Association for 1958. May 28, 1964.

REPORT OF THE NATIONAL SOCIETY, DAUGHTERS OF THE AMERICAN REVOLUTION

In accordance with law, the manuscript of the 66th annual report of the National Society, Daughters of the American Revolution, was transmitted to Congress on February 11, 1964.[1]

DISTRIBUTION PROGRAM

Requests for publications and information concerning them continued to increase during the year. The publications distribution section, under the immediate supervision of Mrs. Eileen M. McCarthy, received 39,017 requests for publications from foreign and domestic libraries, universities, research institutions, educational establishments, and individuals throughout the world. Visitors to the office and replies to inquiries numbered 33,027.

A total of 656,330 copies of publications and miscellaneous items were distributed: 10 Contributions to Knowledge; 16,751 Smithsonian Miscellaneous Collections; 7,912 Annual Report Volumes and 22,686 pamphlet copies of Report separates; 181,568 special publications; 111 reports of the Harriman Alaska Expedition; 62,658 publications of the National Museum; 35,314 publications of the Bureau of American Ethnology; 49,002 catalogs and leaflets of the National Collection of Fine Arts; 148 publications of the Freer Gallery of Art;[2] 7 Annals of the Astrophysical Observatory; 12,965 Smithsonian Contributions to Astrophysics; 678 War Background Studies; 4,987 reports of the American Historical Association; and 53,937 publications not issued by the Smithsonian Institution. Miscellaneous items: 12 sets of North American Wild Flowers and 181 North American Wild Flower prints; 3 Pitcher Plant volumes; 207,400 information leaflets.

The following titles were issued and distributed to libraries as a result of the Institution's participation in the National Science Foundation translation program:

Fauna of U.S.S.R., Fishes, vol. 2, No. 1, Clupeidae, by A. N. Svetovidov; *Fauna of U.S.S.R., Crustacea, vol. 3, No. 3, Freshwater Cyclopoida*, by V. M. Rylov; *Fauna of Russia and Adjacent Countries, Reptiles, vol. 1, Chelonia and Sauria*, by A. M. Nikol'skii; *Genus Woodsia R. Br. in Yugoslavia* (*Genus Woodsia R. Br. V.*

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[1] D.A.R. reports are published as Senate documents and are not available from the Smithsonian Institution.

[2] In addition to those distributed by the Gallery itself.

Jugoslaviji), by E. Mayer; *Morphology, Biology and Zoogeography of European Temnocephala and their Systematic Position*, by J. Matjasic; *Morphological Taxonomical and Typological Problems Concerning Echinocystis Lobata (Michaux) Torrey and Gray*, by V. Petkovsek; *Mammals of U.S.S.R. and Adjacent Countries, vol. 6, Rodents*, by S. I. Ognev; *Fauna and Flora of the Rivers, Lakes and Reservoirs of the U.S.S.R.*, by V. I. Zhadin and S. V. Gerd; *Preparatory Works for the Flora of Slovenia. II., III. II. Odontites Hall, III. Euphrasia L.*, by E. Mayer; A Contribution to the Knowledge *of the Flora of the Western Julian Alps*, by E. Mayer; *Mammals of U.S.S.R. and Adjacent Countries, vol. 7, Rodents*, by S. I. Ognev; *Fauna of U.S.S.R., Crustacea, vol. 7, No. 5*, by Ya. A. Birstein; *Fishes of the Northern Seas of the U.S.S.R.*, by A. P. Andriyashev; *Locusts and Grasshoppers of the U.S.S.R. and Adjacent Countries, part I*, by K. Ya. Bei-Bienko and L. L. Mishchenko; *Locusts and Grasshoppers of the U.S.S.R. and Adjacent Countries, part II*, by G. Ya. Bei-Bienko and L. L. Mishchenko.

INFORMATION PROGRAM

Information activities for the past year included the issuance of 88 news releases on noteworthy events and researches of the Smithsonian. These were utilized extensively by press and other communications media throughout the country. Over 500 written inquiries and more than 1,000 telephone calls for specific information were answered. Approximately 260 visitors, many of them writers and newsmen, sought knowledge concerning the work, facilities, history, and resources of the Institution. Definite plans were made to improve information services in the coming year to meet the needs of a growing population, and to increase the effectiveness of this link between the Institution and the public.

PRINTING PROGRAM

The Smithsonian print shop, a branch of the Government Printing Office, under the immediate supervision of Murray C. Ballard operated at maximum capacity during the past year, completing 552 individual printing jobs. These assignments included labels, forms, invitations, programs, leaflets, flyers, announcements, and other printing of a current and emergency nature.

OTHER ACTIVITIES

The chief of the division continued to represent the Smithsonian Institution on the board of trustees of the Greater Washington Educational Television Association, Inc., of which the Institution is a member. He and the assistant chief of the division represented the

Institution at the annual meeting of the Association of American University Presses held the latter part of May and the first part of June at Chicago, Ill.

The Smithsonian Institution and T.F.H. Publications, Inc., of Jersey City, N.J., in May 1963 entered into an agreement to establish a restricted fund to be known as the "T.F.H. fund for the increase and diffusion of knowledge concerning fishes suitable for home aquaria." T.F.H. will donate to the Smithsonian Institution reprinted books to be sold by the Institution at not less than cost. The money derived from such sales will be earmarked for research, collection or purchase of fish specimens, explorations, and publication of scientific reports related to aquarium fishes. The first reprint under this agreement was published May 18, 1964; it is the four-volume work *The Fishes of North and Middle America*, by David Starr Jordan and Barton Warren Evermann, Bulletin 47 of the U.S. National Museum, originally issued in 1896.

STAFF CHANGES

Three new editors were added to the staff of the division during the past year: Miss Louise J. Heskett on September 30, 1963; Mrs. Nancy Link Powars on December 2, 1963; and Thomas C. Witherspoon on April 14, 1964.

On May 18, 1964, Mrs. Jewell S. Baker was appointed administrative assistant in the division and Miss Sue D. Wallace was appointed clerk-stenographer, following the resignation of Mrs. Margaret L. Poling.

Mrs. Phyllis W. Prescott, who had assisted in editing many of the Bureau of American Ethnology publications, died on June 12, 1964, after a brief illness. She had been associated with the Smithsonian since 1942.

Respectfully submitted.

PAUL H. OEHSER,
Chief, Editorial and Publications Division.

S. DILLON RIPLEY,
Secretary, Smithsonian Institution.

Report of the Executive Committee of the Board of Regents of the Smithsonian Institution

For the Year Ended June 30, 1964

To the Board of Regents of the Smithsonian Institution:

Your executive committee respectfully submits the following report in relation to the funds of the Smithsonian Institution, together with a statement of the appropriations by Congress for the Government bureaus in the administrative charge of the Institution.

SMITHSONIAN INSTITUTION

PARENT FUND

The original bequest of James Smithson was £104,960 8s 6d—$508,318.46. Refunds of money expended in prosecution of the claim, freight, insurance, and other incidental expenses, together with payment into the fund of the sum of £5,015, which had been withheld during the lifetime of Madame de la Batut, brought the fund to the amount of $550,000.

The gift of James Smithson was "lent to the United States Treasury, at 6 per centum per annum interest" (20 USC. 54) and by the Act of March 12, 1894 (20 USC. 55) the Secretary of the Treasury was "authorized to receive into the Treasury, on the same terms as the original bequest of James Smithson, such sums as the Regents may, from time to time see fit to deposit, not exceeding, with the original bequest the sum of $1,000,000."

The maximum of $1,000,000 which the Smithsonian Institution was authorized to deposit in the Treasury of the United States was reached on January 11, 1917, by the deposit of $2,000.

Under the above authority the amounts shown below are deposited in the United States Treasury and draw 6 percent interest:

	Unrestricted funds	*Income 1964*
James Smithson	$727, 640	$43, 658. 40
Avery	14, 000	840. 00
Habel	500	30. 00
Hamilton	2, 500	150. 00
Hodgkins (General)	116, 000	6, 960. 00
Poore	26, 670	1, 600. 20
Rhees	590	35. 40
Sanford	1, 100	66. 00
Total	$889, 000	$53, 340. 00

	Restricted funds	*Income 1964*
Hodgkins (Specific)	$100, 000	$6, 000. 00
Reid	11, 000	660. 00
Total	$111, 000	6, 660. 00
Grand total	$1, 000, 000	$60, 000. 00

In addition to the $1,000,000 deposited in the Treasury of the United States there has been accumulated from income and bequests the sum of $7,233,033.28 which has been invested. Of this sum, $6,278,181.67 is carried on the books of the Institution as the Consolidated Fund, a policy approved by the Regents at their meeting on December 14, 1916. The balance is made up of several small funds.

CONSOLIDATED FUND

(Income for the unrestricted use of the Institution)

Fund	Investment 1964	Income 1964
Abbott, W. L., Special	$24, 177. 94	$1, 082. 49
*Avery, Robert S., and Lydia	64, 101. 76	2, 870. 00
Forrest, Robert Lee, Bequest	1, 753, 815. 43	65, 850. 57
Gifts, royalties, gain on sale of securities	448, 086. 13	20, 062. 27
Hachenberg, George P. and Caroline	6, 526. 73	292. 20
*Hamilton, James	655. 07	29. 32
Hart, Gustavus E	790. 43	35. 37
Henry, Caroline	1, 962. 71	87. 86
Henry, Joseph and Harriet A	79, 553. 39	3, 561. 78
*Hodgkins, Thomas C. (General)	49, 160. 26	2, 201. 04
Morrow, Dwight W	125, 493. 59	5, 618. 63
Olmsted, Helen A	1, 301. 09	58. 27
*Poore, Lucy T. and George W	264, 125. 96	11, 825. 56
Porter, Henry Kirke	464, 776. 51	20, 809. 16
*Rhees, William Jones	767. 77	34. 36
*Sanford, George H	1, 444. 61	64. 69
*Smithson, James	1, 981. 23	88. 73
Taggart, Gansen	580. 42	25. 97
Higbee, Harry, Memorial Fund	19, 019. 89	851. 59
Witherspoon, Thomas A	209, 430. 31	9, 376. 68
Total	$3, 517, 751. 23	$144, 826. 54

*In addition to funds deposited in the United States Treasury.

766-746—65——19

CONSOLIDATED FUND—Continued

(Income restricted to specific use)

Fund	Investment 1964	Income 1964
Abbott, William L., for investigations in biology	$169, 186. 94	$7, 574. 92
Armstrong, Edwin James, for use of Department of Invertebrate Paleontology when principal amounts to $5,000	2, 237. 37	95. 89
Arthur, James, for investigations and study of the sun and annual lecture on same	64, 903. 62	2, 905. 87
Bacon, Virginia Purdy, for traveling scholarship to investigate fauna of countries other than the United States	81, 306. 56	3, 640. 28
Baird, Spencer Fullerton, for expenses in whole or in part of a scientific exploration and biological research or for the purchase of specimens of natural objects or archeological specimens	59, 500. 00	2, 663. 95
Barney, Alice Pike, for collection of paintings and pastels and for encouragement of American artistic endeavor	46, 546. 23	2, 083. 96
Barstow, Frederick D., for purchase of animals for Zoological Park	1, 622. 40	72. 62
Brown, Roland W., endowment fund—study, care, and improvement of the Smithsonian paleobotanical collections	52, 861. 91	2, 366. 75
Canfield collection, for increase and care of the Canfield collection of minerals	62, 069. 64	2, 779. 01
Casey, Thomas I., for maintenance of the Casey collection and promotion of researches relating to Coleoptera	20, 341. 68	910. 72
Chamberlain, Francis Lea, for increase and promotion of Isaac Lea Collection of gems and mollusks	45, 700. 54	2, 046. 11
Dykes, Charles, for support in financial research	69, 869. 81	3, 128. 24
Eickemeyer, Florence Brevoort, for preservation and exhibition of the photographic collection of Rudolph Eickemeyer, Jr	17, 639. 63	789. 79
Guggenheim, Daniel and Florence Foundation for a commemorative Guggenheim Exhibit, an annual Daniel Guggenheim Lecture, and annual Guggenheim Fellowships for graduate students for research at the National Air Musuem	25, 000. 00	0
Hanson, Martin Gustav and Caroline Runice, for some scientific work of the Institution, preferably in chemistry or medicine	14, 427. 04	645. 92
Higbee, Harry, income for general use of the Smithsonian Institution after June 11, 1967	689. 63	78. 59
Hillyer Virgil, for increase and care of Virgil Hillyer collection of lighting objects	10, 665. 69	477. 54

CONSOLIDATED FUND—Continued

(Income restricted to specific use)—Continued

Fund	Investment 1964	Income 1964
Hitchcock, Albert S., for care of the Hitchcock Agrostological Library	$2, 560. 76	$114. 65
Hrdlička, Aleš and Marie, to further researches in physical anthropology and publication in connection therewith	89, 665. 38	3, 842. 51
Hughes, Bruce, to found Hughes alcove	31, 063. 71	1, 390. 79
Johnson, E. R. Fenimore, research in under-water Photography	12, 428. 22	819. 28
Loeb, Morris, for furtherance of knowledge in the exact sciences	141, 436. 88	6, 332. 49
Long, Annette and Edith C., for upkeep and preservation of Long collection of embroideries, laces, and textiles	881. 16	39. 46
Maxwell, Mary E., for care and exhibition of Maxwell collection	31, 831. 06	1, 425. 15
Myer, Catherine Walden, for purchase of first-class works of art for use and benefit of the National Collection of Fine Arts	32, 780. 17	1, 467. 64
Nelson, Edward W., for support of biological studies	38, 626. 19	1, 682. 71
Noyes, Frank B., for use in connection with the collection of dolls placed in the U.S. National Museum through the interest of Mr. and Mrs. Noyes	1, 559. 12	69. 83
Pell, Cornelia Livingston, for maintenance of Alfred Duane Pell collection	12, 029. 31	538. 56
Petrocelli, Joseph, for the care of the Petrocelli collection of photographic prints and for the enlargement and development of the section of photography of the U.S. National Museum	12, 030. 75	538. 65
Rathbun, Richard, for use of division of U.S. National Museum containing Crustacea	17, 260. 69	772. 81
*Reid, Addison T., for founding chair in biology, in memory of Asher Tunis	28, 866. 03	1, 292. 38
Roebling Collection, for care, improvement, and increase of Roebling collection of minerals	195, 860. 04	8, 769. 12
Roebling Solar Research	40, 695. 49	1, 822. 04
Rollins, Miriam and William, for investigations in physics and chemistry	242, 033. 39	10, 599. 15
Smithsonian employees' retirement	37, 423. 68	1, 691. 20
Springer, Frank, for care and increase of the Springer collection and library	29, 102. 46	1, 302. 98
Strong, Julia D., for benefit of the National Collection of Fine Arts	16, 226. 11	726. 48
Walcott, Charles D. and Mary Vaux, for development of geological and paleontological studies and publishing results of same	778, 915. 07	34, 842. 24

CONSOLIDATED FUND—Continued

(Income restricted to specific use)—Continued

Fund	Investment 1964	Income 1964
Walcott, Mary Vaux, for publication in botany	$93, 939. 64	$4, 205. 91
Younger, Helen Walcott, held in trust	127, 107. 05	6, 500. 71
Zerbee, Francis Brinckle, for endowment of aquaria	1, 539. 39	68. 91
Total	$2, 760, 430. 44	$121, 416. 45

FREER GALLERY OF ART FUND

Early in 1906, by deed of gift, Charles L. Freer, of Detroit, gave to the Institution his collection of Chinese and other Oriental subjects of art, as well as paintings, etchings, and other works of art by Whistler, Thayer, Dewing, and other artists. Later he also gave funds for construction of a building to house the collection, and finally in his will, probated November 6, 1919, he provided stocks and securities to the estimated value of $1,958,591.42, as an endowment fund for the operation of the Gallery. The fund now amounts to $10,987,835.54.

SUMMARY OF ENDOWMENTS

Invested endowment for general purposes	$5, 243, 151. 23
Invested endowment for specific purposes other than Freer endowment	2, 989, 882. 05
Total invested endowment other than Freer	8, 233, 033. 28
Freer invested endowment for specific purposes	10, 987, 835. 34
Total invested endowment for all purposes	$19, 220, 868. 62

CLASSIFICATION OF INVESTMENTS

Deposited in the U.S. Treasury at 6 percent per annum, as authorized in the U.S. Revised Statutes, sec. 5591		$1, 000, 000. 00
Investments other than Freer endowment (cost or market value at date acquired):		
Bonds	$2, 641, 924. 90	
Stocks	3, 601, 024. 68	
Real estate and mortgages	951, 406. 00	
Uninvested capital	38, 677. 70	7, 233, 033. 28
Total investments other than Freer endowment		8, 233, 033. 28
Investments of Freer endowment (cost or market value at date acquired):		
Bonds	$6, 032, 418. 24	
Stocks	4, 954, 472. 28	
Uninvested capital	944. 82	10, 987, 835. 34
Total investments		$19, 220, 868. 62

EXHIBIT A

BALANCE SHEET OF PRIVATE FUNDS

June 30, 1964

ASSETS

Current funds:			
General:			
Cash:			
United States Treasury current account			$76,965.48
In banks and on hand			155,713.17
			232,678.65
Investments—stocks and bonds (quoted market value $2,020,111.00 [1]			2,030,531.30
Travel and other advances			13,983.65
Total general funds			2,277,193.60
Restricted:			
Cash—United States Treasury current account		$1,731,447.28	
Investments—stocks and bonds (quoted market value $496,064.00) (note)		498,641.63	
Total restricted funds			2,230,088.91
Total current funds			4,507,282.51
Endowment funds and funds functioning as endowment:			
Investments:			
Freer Gallery of Art:			
Cash		944.82	
Stocks and bonds (quoted market value $17,404,618.00) (note)		10,986,890.52	
		10,987,835.34	
Consolidated:			
Cash	$27,875.21		
Stocks and bonds (quoted market value $7,924,024.00) (note)	6,113,080.63		
	6,140,955.84		
Loan to United States Treasury	1,000,000.00		
Other stocks and bonds (quoted market value $182,068.00) (note)	129,868.95		
Cash	10,802.49		
Real estate	951,406.00	8,233,033.28	
Total endowment funds and funds functioning as endowment			$19,220,868.62
Total			$23,728,151.13

[1] Investments are stated at cost or appraisal value at date of gift.

FUND BALANCES

Current funds:			
General:			
Unexpended funds—unrestricted			$2,277,193.60
Total general funds			2,277,193.60
Restricted:			
Unexpended income from endowment		$1,292,324.13	
Funds for special purposes:			
Gifts		514,631.55	
Grants		1,216,815.73	
Contracts		(793,682.50)	
Total restricted funds			2,230,088.91
Total current funds			4,507,282.51
Endowment funds and funds functioning as endowment:			
Freer Gallery of Art		10,987,835.34	
Other:			
Restricted	$2,989,882.05		
General	5,243,151.23		
		8,233,033.28	
Total endowment funds and funds functioning as endowment			19,220,868.62
Total			$23,728,151.13

EXHIBIT B

PRIVATE FUNDS

STATEMENT OF CURRENT GENERAL FUND RECEIPTS AND DISBURSEMENTS AND CHANGES IN CURRENT GENERAL FUND BALANCE

Year ended June 30, 1964

	Operations	Gifts	Grants	Contracts	Total
Current receipts:					
Endowment income:					
Freer Gallery of Art	$648, 817. 36				$648, 817. 36
Other restricted funds	139, 314. 31				139, 314. 31
Unrestricted	145, 336. 67				145, 336. 67
Investment income	111, 611. 32				111, 611. 32
Gifts and grants	1, 426, 338. 48	$901, 560. 79	$5, 628, 739. 80	$2, 533, 123. 31	10, 489, 762. 38
Publications and photographs	169, 274. 93				169, 274. 93
Miscellaneous	6, 801. 44				6, 801. 44
Total current receipts	2, 647, 494. 51	901, 560. 79	5, 628, 739. 80	2, 533, 123. 31	11, 710, 918. 41
Current disbursements:					
Salaries:					
Administrative	694, 227. 39			10, 474. 03	704, 701. 42
Research	87, 979. 40	14, 768. 89	2, 832, 351. 22	261, 985. 98	3, 197, 085. 49
Other	13, 123. 71	56, 605. 24	17, 546. 03	9, 459. 87	96, 734. 85
Employee benefits	26, 466. 56		111, 227. 74	8, 223. 62	145, 897. 92
Total salaries	821, 777. 06	71, 374. 13	2, 961, 124. 99	290, 143. 50	4, 144, 419. 68
Purchase for collection	276, 700. 91	500, 000. 00	35, 000. 00		811, 700. 91

EXHIBIT B—Continued

PRIVATE FUNDS—Continued

	Operations	Gifts	Grants	Contracts	Total
Current disbursements—Continued					
Researches and exploration and related administrative expenses:					
Travel	$44, 046. 92	$91, 819. 56	$429, 785. 12	$165, 459. 74	$731, 111. 34
Equipment and supply	42, 578. 83	5, 919. 46	170, 515. 75	67, 546. 67	286, 560. 71
Other	51, 521. 02				51, 521. 02
Publication and photographs	162, 406. 54	3, 771. 74			166, 178. 28
Buildings, equipment and grounds:					
Buildings and installations	15, 685. 22		3, 296. 92		18, 982. 14
Court and grounds maintenance	2, 243. 89				2, 243. 89
Technical laboratory	4, 049. 80				4, 049. 80
Rents and utilities			440, 636. 65	33, 440. 04	474, 076. 69
Contractual services:					
Computer			578, 080. 49	7, 327. 21	585, 407. 70
Subcontracts			13, 375. 00	1, 606, 486. 61	1, 619, 861. 61
Other services	155, 227. 33	145, 830. 92	605, 556. 22	305, 350. 27	1, 211, 964. 74
Supplies and expenses:					
Meetings, special exhibits	20, 182. 57				20, 182. 57
Lectures	2, 968. 55				2, 968. 55
Photographs and reproductions	2, 726. 09	72, 168. 57	3, 711. 59		78, 606. 25
Library	4, 179. 27				4, 179. 27
Sales desk	12, 311. 96				12, 311. 96
Stationery and office supplies	14, 757. 97	7, 338. 03	249, 506. 31	45, 970. 62	317, 572. 93
Postage, telephone and telegraph	5, 935. 54	3, 338. 38	138, 150. 76	11, 398. 65	158, 823. 33

Employees' withholding payments, net	(6, 753. 67)				(6, 753. 67)
Total current disbursements	1, 632, 545. 80	901, 560. 79	5, 628, 739. 80	2, 533, 123. 31	10, 695, 969. 70
Excess of current receipts over current disbursements, carried forward	1, 014, 948. 71				1, 014, 948. 71
Excess of current receipts over current disbursements, brought forward	1, 014, 948. 71				1, 014, 948. 71
Transfer to restricted fund	(10, 000. 00)				(10, 000. 00)
Transfer to endowments	(1, 370, 264. 44)				(1, 370, 264. 44)
Transfer from gifts and grants	1, 168, 314. 86				1, 168, 314. 86
	802, 999. 13				802, 999. 13
Balance at beginning of year	1, 474, 194. 47				1, 474, 194. 47
Balance at end of year	2, 277, 193. 60				2, 277, 193. 60

EXHIBIT C

PRIVATE FUNDS

STATEMENT OF CHANGES IN CURRENT RESTRICTED FUND BALANCE

Year ended June 30, 1964

	Unexpended income	Funds for special purposes			Total
		Gifts	Grants	Contracts	
Balance at beginning of year	$1, 384, 769. 95	$388, 800. 64	$3, 389, 774. 30	($188, 644. 30)	$4, 974, 700. 59
Add:					
Income from endowment:					
Freer Gallery of Art	516, 683. 51				516, 683. 51
Other restricted funds	132, 605. 79				132, 605. 79
Unrestricted funds	144, 826. 54				144, 826. 54
	794, 115. 84				794, 115. 84
Less administrative costs	43, 816. 77				43, 816. 77
Net income from endowment	750, 299. 07				750, 299. 07
Sale of publications	29, 741. 47	1, 446. 22			31, 187. 69
Gifts and grants		822, 219. 83	4, 957, 333. 60	2, 231, 779. 47	8, 011, 332. 90

Traveling exhibition		225, 799. 13			225, 799. 13
Other	4, 907. 99	949. 82	360. 83		6, 218. 64
	784, 948. 53	1, 050, 415. 00	4, 957, 694. 43	2, 231, 779. 47	9, 024, 837. 43
	2, 169, 718. 48	1, 439, 215. 64	8, 347, 468. 73	2, 043, 135. 17	13, 999, 538. 02
Deduct:					
Transfer to current income, net of administrative costs:					
Freer Gallery of Art	607, 650. 00				607, 650. 00
Other restricted funds	136, 664. 90	901, 560. 79	5, 628, 739. 80	2, 533, 123. 31	9, 200, 088. 80
Unrestricted funds	145, 336. 67				145, 336. 67
	889, 651. 57	901, 560. 79	5, 628, 739. 80	2, 533, 123. 31	9, 953, 075. 47
Refund of prior years' unexpended funds			647, 816. 00		647, 816. 00
Transfer	(10, 349. 82)	10, 523. 30	854, 097. 20	303, 694. 36	1, 157, 965. 04
Income added to principal, net	10, 592. 60				10, 592. 60
Transfer to (from) gifts	(12, 500. 00)	12, 500. 00			
	877, 394. 35	924, 584. 09	7, 130, 653. 00	2, 836, 817. 67	11, 769, 449. 11
Balance at end of year	1, 292, 324. 13	514, 631. 55	1, 216, 815. 73	(793, 682. 50)	2, 230, 088. 91

EXHIBIT D

PRIVATE FUNDS

STATEMENT OF CHANGES IN PRINCIPAL OF ENDOWMENT FUNDS AND FUNDS FUNCTIONING AS ENDOWMENT

Year ended June 30, 1964

Balance at beginning of year		$16,086,025.07
Add:		
Gifts and bequests		1,211,648.50
Income added to principal as prescribed by donor		10,596.00
Transfer from current fund for investment		1,370,621.19
Net gain on investments		542,684.43
		19,221,575.19
Less:		
Transfer to cover deficit in employees' retirement fund	$349.82	
Income paid to income beneficiary as prescribed by donor	356.75	
		706.57
Balance at end of year		$19,220,868.62
Balance at end of year consisting of:		
Freer Gallery of Art		10,987,835.34
Other:		
Restricted		2,989,882.05
General		5,243,151.23
		$19,220,868.62

The practice of maintaining savings accounts in several of the Washington banks and trust companies has been continued during the past year, and interest on these deposits amounted to $7,817.98.

Deposits are made in banks for convenience in collection of checks, and later such funds are withdrawn and deposited in the United States Treasury. Disbursement of funds is made by check signed by the Secretary of the Institution and drawn on the United States Treasury.

The Institution gratefully acknowledges gifts and grants from the following:

Anonymous, a gift for special purposes.

Atomic Energy Commission, a grant for research entitled "A Study of the Biochemical Effects of Ionizing and Nonionizing Radiation on Plant Metabolism during Development."

Boston University, a grant to defray travel expenses to the West Coast to study research materials.

Bredin Foundation, a grant for the support of research entitled "Biological Survey of Dominica Project."
A grant for the support of research entitled "Ocean Food Chain Cycle."

David K. E. Bruce, a gift for special purposes.

Mary Grace Bruce, a gift for special purposes.

Mrs. J. Campbell, a gift to the Zoo Animal Fund.

Department of the Air Force: Additional grant for the support of research entitled "Study of Atomic and Electronic Collision Processes which occur in the Atmosphere at Auroral Heights."
A grant for studies directed toward the development of a technique for measuring wind speed and direction at heights using ionized paths generated by meteors.
A grant for the exploration of computer techniques in the preparation of indexes.
A grant to prepare and conduct a course in operation maintenance and calibration training for seven government personnel on the Baker-Nunn Camera System.
A grant to perform numerical analysis of observational data to determine the rate of satellite period.
A grant for time standard calibrating training and consulting in support for the "Field and Precision Reduction of Baker-Nunn Film."

Department of the Army: Additional grant for the support of basic research entitled "Potential Vectors and Reservoirs of Disease in Strategic Overseas Area."
Additional grant for the support of research entitled "Mammals and their Ectoparasites from Iran."
Additional grant for support of research on the analysis of bird migration in the Pacific Area and the study of the ecology of birds and mammals on one or more Pacific Islands.
A grant for research entitled "Bio-Ecological Classification for Military Environments."

Ethyl Corporation, a gift for the S. D. Heron Memorial Fund.

Robert Lee Forrest Bequest for unrestricted use of Smithsonian Institution.

Esther Goddard, a gift to the Goddard Memorial Fund.

Robert H. Groh, a gift for the purchase of Egyptian Bronze Situla.

Guggenheim, Daniel and Florence, Foundation for a commemorative Guggenheim Exhibit, an annual Daniel Guggenheim Lecture, and annual Guggenheim Fellowships for graduate students for research at the National Air Museum.

Felix and Helen Juda, a gift to the Freer Gallery of Art, for the purchase of collections.

Joseph H. Kler, a gift for the Delaware Log House Exhibit Fund.

Landegger Foundation Inc., a gift for research entitled "The Landegger Underwater Exploration."

Link Foundation, a grant for the publication of the pamphlet "Opportunities in Oceanography."

James H. Means, a gift for the James Means and the Problem of Manflight Fund.

Paul Mellon, a contribution for the Traveling Exhibition Service.

Vera C. Murray, a gift for the purchase of two historic aircraft engines.

National Aeronautics and Space Administration: Additional grant for the support of research entitled "Optical Satellite Tracking Program."
Additional grant for the scientific and engineering study for instrumenting and orbiting telescope.
A grant for research entitled "Optical and Radar Investigation of Simulated and Natural Meteors."
A grant for research entitled "Computation of Data Reduction of S-16 High Energy Gamma-Ray Experiment."
A grant for research studies in the recovery and analysis of space fragments.
A grant for an investigation and collection of meteorites, tektites, and related materials.

National Geographic Society: Additional grant for research entitled "Link Prolonged and Deep Submergence Study Program."
A grant for research expedition to Australia.
A grant for publication entitled "Archeology of Pueblo Bonito."

National Institutes of Health: Additional grant for research entitled "Studies of Asian Biting Flies."
Additional grant for the support of research entitled "Generic Classification of the Proctotrupoidea."
A grant for the support of research entitled "Chronic Disease in Relation to Social Efficiency."

National Science Foundation: Additional grant for the support of research entitled "Early Tertiary Mammals of North America."
Additional grant for the support of research entitled "Earth Albedo Observations."
Additional grant for the support of research entitled "Revisionary Study of Blattoidea."
Additional grant for the support of research entitled "Rare Gases in Meteorites."
Additional grant for the support of research entitled "Morphology and Paleoecology of Permian Brachiopods of the Glass Mountain, Texas."
Additional grant for the support of research entitled "Tertiary Forests of the Tonasi-Santiago Basin of Panama."

Additional grant for the support of research entitled "South Asian Microlepidoptera, particularly the Philippine Series."
Additional grant for the support of research entitled "The Mammals of Panama."
Additional grant for the support of research entitled "Ecology and Behavior of *Suncus murinus*."
Additional grant for the support of research entitled "Photoresponse and Optical Properties of Phycomyces Sporangiophores."
Additional grant for the support of research entitled "Taxonomy of Bamboos."
Additional grant for the support of research entitled "Lower Cretaceous Ostracoda of Israel."
Additional grant for the support of research entitled "Marine Mollusks of Polynesia."
Additional grant for the support of research entitled "Tertiary Echinoids of the Eastern United States and the Caribbean."
Additional grant for the support of research entitled "Monographic Revision of Carcharinid Sharks of the Tropical Indo-Pacific Oceans."
Additional grant for the support of research entitled "Zoogeography of Southern Ocean Sclearactinian Coral Faunas."
Additional grant for the support of research entitled "The American Commensal Crabs of the Family Pinnotheridae."
Additional grant for the support of research entitled "Prehistory of Southwest, Virginia."
Additional grant for the support of research entitled "Indo-Australian Vespidae sens. lat. and Specidae."
Additional grant for the support of research entitled "Support of Publication of an English Translation of Flora of Japan, by Jisaburo Ohwi."
Additional grant for the support of research entitled "Revision of Genera of Paleozoic Bryozoa."
Additional grant for the support of research entitled "Research of Stellar Atmosphere."
Additional grant for the support of research entitled "Monographic Studies of the Tingidae of the World."
Additional grant for the support of research entitled "Ethnoscientific Analysis of American Ethnology."
Additional grant for the support of research entitled "Pelagic Phosphorus Metabolism: Phosphorus-containing Compounds in Plankton."
Additional grant for the support of research entitled "Study of Type Specimens of Ferns in European Herbaria."
Additional grant for the support of research entitled "Polychaetous Annelids of New England."
Additional grant for the support of research entitled "The Phanerogams of Colombia."
Additional grant for the support of research entitled "Monograph of Parmelia Subgenus *Xanthoparmelia*."
Additional grant for the support of research entitled "Revision of Scarab Beetles of the Genus *Ataenius*."
Additional grant for the support of research entitled "Systemic Studies of the Archidaceae, Subtribe Epidendrinae."
Additional grant for the support of research entitled "A Monograph of the Stomatopod Crustaceans of the Western Atlantic."

Additional grant for the support of research entitled "Recording of Data for Specimens Collected during the U.S. Antarctic Program."

Additional grant for the support of research entitled "Mammals of Southeastern United States."

Additional grant for the support of research entitled "Exploration in Southern Brazil."

Additional grant for the support of research entitled "Distribution of North America Calanoid and Harpacticoid Copepoda."

Additional grant for the support of research entitled "Megalithic Structures of *Panope*."

Additional grant for the support of research entitled "Collection of Meteorites and Tektites in Australia."

Additional grant for the support of research entitled "Installation of Power Line to Barro Colorado from Mainland."

Additional grant for the support of research entitled "European Tertiary Dicotyledon Floras."

Additional grant for the support of research entitled "Science Information Exchange."

Additional grant for the support of research entitled "Geographic Variation in the Inter-specific Relations among Certain Andean Passeriformes."

Additional grant for the support of research entitled "Upper Cretaceous Inoceraminae in North America and Western Europe."

Additional grant for the support of research entitled "Environment of Permo-Triassic Reptiles of the Order Therapsida in South Africa."

Additional grant for the support of research entitled "Taxonomic and Biological Studies of Neotropical Water Beetles."

Additional grant for the support of research entitled "Evolution and Distribution of *Parmelia* in Eastern Asia and Pacific."

Additional grant for the support of research entitled "Sorting of U.S. Antarctic Research Program Biological Collections."

Additional grant for the support of research entitled "Taxonomic Studies of the Family Stenomidae in Neotropical Region."

Additional grant for the support of research entitled "Pre-Industrial System of Water Management in Arid Region."

Additional grant for the support of research entitled "Effects of Displacement."

Additional grant for the support of research entitled "Revisionary Studies in the Chilopoda."

Additional grant for the support of research entitled "Photographic Investigation of Comets."

Additional grant for the support of research entitled "Purchase of the Hood Collection of Thrips."

Additional grant for the support of research entitled "Archaeological Survey of Southwestern Kansas."

Additional grant for the support of research entitled "Taxonomic and Biological Studies on Central American Caddisflies."

Neinken Foundation, a gift for philately research.

Office of Naval Research: Additional grant to perform aeronautical research studies.

Additional grant to provide expert consultants to advise the Navy Advisory Committee.

Additional grant to perform psychological research studies.

Additional grant for the support of research entitled "Information of Shark Distribution and Distribution of Shark Attack All Over the World."

Additional grant for studies concerning the development of a proposal for an institute for laboratory of human performance standards.

A grant for research entitled "Microlepidoptera of the Island of Rapa."

A grant to conduct research on the Medusae and related organisms from the Indian Ocean Collection.

O'Neill Brothers Foundation, a gift for the purchase of rare Alaskan notes for numismatic collection.

Charles Pfizer and Company, a gift for purchase of objects for exhibits on the history of pharmacy.

Rockefeller Foundation, a grant for research entitled "Bird Virus Diseases in the Region of Belem, Brazil."

Mr. and Mrs. R. Tom Sawyer, a gift for the Tom Sawyer—Model of the first Gas Turbine Locomotive Fund.

Frank R. Schwengel, a gift toward the study of mollusks of Polynesia.

For the support of the Science Information Exchange:

Atomic Energy Commission
Department of Defense
National Institutes of Health
National Science Foundation

Jerome A. Straka, a gift for the purchase of the antique Feregham carpet.

For the support of the Taiwan Photographic Project:

Bollingen Foundation
Henry Luce Foundation
Rockefeller Foundation

Ellen Bayard Weedon Foundation, a gift to the Freer Gallery of Art for the Library Fund.

Wenner Gren Foundation, a gift for anthropological research entitled "To Aid Study of Rapid Change and Adjustment under Conditions of Shock and Territorial Displacement among Canela of Brazil."

Westinghouse Corporation, a contribution toward the dismantling and transportation of one of the original generators at the Niagara Falls Power Company.

Woods Hole Marine Biological Laboratory, a gift for marine biological research (Buzas).

Woods Hole Oceanographic Institution, a gift to provide funds to permit the participation in the International Indian Ocean Expedition.

Charles Mortiz Wormser, a gift for the Mortiz Wormser Memorial Fund.

766-746—65——20

The following appropriations were made by Congress for the Government bureaus under the administrative charge of the Smithsonian Institution for the fiscal year 1964:

Salaries and expenses	$13,191,000.00
National Zoological Park	$1,597,356.00
The appropriation made to the National Gallery of Art (which is a bureau of the Smithsonian Institution) was	$2,138,000.00

In addition, funds were transferred from other Government agencies for expenditure under the direction of the Smithsonian Institution as follows:

Working funds, transferred from the National Park Service, Interior Department, for archeological investigations in river basins throughout the United States	$254,500.00

The Institution also administers a trust fund for partial support of the Canal Zone Biological Area, located on Barro Colorado Island in the Canal Zone.

ROBERT LEE FORREST BEQUEST

The final settlement was made during the year by the Mercantile Safe Deposit and Trust Company of Baltimore, Md., as executors of the will of Robert Lee Forrest, who died on October 30, 1962. The Smithsonian Institution was named in the will as the residuary legatee.

The distribution resulted in the following being received by and for the unrestricted use of the Smithsonian Institution:

Cash received	$1,370,621.19
5,498 shares of The Borden Company, fair market value	347,748.50

In addition to the above there was received three parcels of real property consisting of a farm known as "Java Farm," located in Anne Arundel County, Md., of approximately 360 acres; one lot and improvements located at 7–11 Chesapeake Street, Towson, Md., one unimproved lot located at 700 N. Kresson Street, Baltimore, Md. There also was received some odd lots of stock of "no value" which included 22 shares, preferred, of The Municipal Asphalt Company, 30 shares, Common, of the Municipal Asphalt Company, 100 shares of The Fast Bearing Company, and 100 shares of Medical Chemicals, Incorporated.

AUDIT

The report of the audit of the Smithsonian Private Funds follows:

THE BOARD OF REGENTS
Smithsonian Institution
Washington, D.C., 20560

We have examined the balance sheet of private funds of Smithsonian Institution as of June 30, 1964 and the related statement of current general private funds receipts and disbursements and the several statements of changes in

funds for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

Except for certain real estate acquired by gift or purchased from proceeds of gifts which are valued at cost or appraised value at date of gift, land, buildings, furniture, equipment, works of art, living and other specimens and certain sundry property are not included in the accounts of the Institution; likewise, the accompanying statements do not include the National Gallery of Art, the John F. Kennedy Center for the Performing Arts and other departments, bureaus and operations administered by the Institution under Federal appropriations. The accounts of the Institution are maintained on the basis of cash receipts and disbursements, with the result that the accompanying statements do not reflect income earned but not collected or expenses incurred but not paid.

In our opinion, subject to the matters referred to in the preceding paragraph, the accompanying statement of private funds presents fairly the assets and funds principal of Smithsonian Institution at June 30, 1964; further, the accompanying statement of current general private funds receipts and disbursements and several statements of changes in funds, which have been prepared on a basis consistent with that of the preceding year, present fairly the cash transactions of the private funds for the year then ended.

(S) PEAT, MARWICH, MITCHELL & CO.

WASHINGTON, D.C.
October 16, 1964

Respectfully submitted:

(S) ROBERT V. FLEMING,
(S) CARYL P. HASKINS,
(S) CLINTON P. ANDERSON,
Executive Committee.

GENERAL APPENDIX

to the

SMITHSONIAN REPORT FOR 1964

PREFACE

The object of the General Appendix to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by staff members and collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution from a very early date to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and, during the greater part of its history, this purpose has been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880, induced in part by the discontinuance of an annual summary of progress which for 30 years previously had been issued by well-known private publishing firms, the Secretary had a series of abstracts prepared by competent collaborators, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report of 1889, a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report for 1964.

An "Author-Subject Index to Articles in Smithsonian Annual Reports, 1849–1961" (Smithsonian Publication 4503) was issued in 1963.

Reprints of the various papers in the General Appendix may be obtained, as long as the supply lasts, on request addressed to the Editorial and Publications Division, Smithsonian Institution, Washington, D.C., 20560.

The Quest for Life Beyond the Earth[1]

By Carl Sagan

Staff member, Smithsonian Astrophysical Observatory, and Assistant Professor of Astronomy, Harvard University

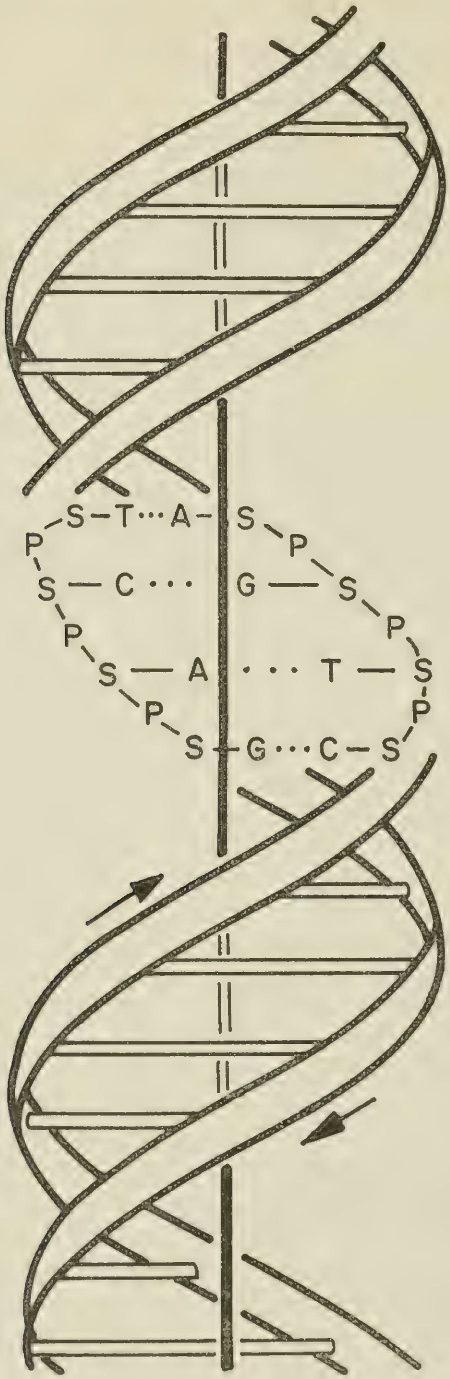
[With 4 plates]

We are not alone in the universe. Among the countless galaxies, each with billions of stars, there must be many planets on which life is now flourishing. Unfortunately, there is little prospect of travel to these distant worlds—at least for the next century or so—and statistical arguments do not satisfy that amalgam of scientific curiosity and the love of high adventure which motivates the search for the beings of other planets.

But it may not be necessary to venture beyond our solar system. The possibility that neighboring planets are inhabited, at least by simple organisms, is a concept that is both very old and very popular. Its immediate appeal, however, should be tempered by the facts. Despite the wide range of studies which have already been performed, we do not know whether the other planets of our solar system are inhabited. The problem often reduces to probability considerations, and to estimates of observational reliability. At convenient places in the following discussion I shall try to pause and give brief expression to alternative interpretations. In almost all cases, an optimistic view can be found which holds that the evidence is strongly suggestive of, or, at the worst, not inconsistent with, the existence of extraterrestrial life; and a pessimistic view can be found, which holds that the evidence adduced in favor of extraterrestrial life is unconvincing, irrelevant, or has an alternative, nonbiological explanation. I leave it to the reader to pick his own way among the factions.

Extraterrestrial life and the origin of life are questions intertwined. If it appears relatively easy for life to have emerged in the primitive terrestrial environment, it may follow that the origin of life is a fairly general planetary phenomenon. So let us begin with a discussion of

[1] The A. Calvert Smith prize-winning essay at Harvard University for 1964. Reprinted by permission from *Harvard Alumni Bulletin*, April 4, 1964.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recent ideas on the origin of life on Earth some 4 billion years ago, and then continue with a discussion of the physical environments of the moon and planets, and finally, a look at the more direct evidence for life beyond the Earth.

When life began depends upon the definition of life, and, curiously enough, there is no definition acceptable to all biologists. Yet, the many characteristic features of living systems—their complex and highly structured forms, their growth, metabolism, and reproduction—are all ultimately attributable to evolution by natural selection. And evolution occurs in plants and animals because of the interaction of the environment with the hereditary material, a kind of molecular blueprint which controls metabolism, produces a replica of itself for the next generation to follow, and, through the centuries, gradually changes, or mutates, occasioning new forms of life. The key molecules of the hereditary material are the nucleic acids, ribonucleic acid (RNA) and deoxyribonucleic acid (DNA). Thus, the problem of the origin of life seems to be connected with the problem of the origin of nucleic acids.

The structure and function of DNA have been elucidated chiefly by James D. Watson, of Harvard, and Francis H. C. Crick, of Cambridge University. It is a long molecule, comprising two molecular strands wound about each other in a coil, or helix. During cell division, the strands separate, and each synthesizes a copy of the other, yielding two molecules of DNA where originally there was one. The building blocks for this synthesis are called nucleoside phosphates, and much of the activity of the cell is devoted to constructing these building blocks from yet simpler molecules, and joining them together to form nucleic acids. The nucleoside phosphates are each composed of a sugar, a base, and one, two, or three phosphates. A given nucleic acid molecule is generally composed of four kinds of nucleoside phosphates. Their sequencing along the chain is a kind of four-letter code that determines which proteins a cell will make. Proteins, in turn, are long chains of amino acids, and recent evidence indicates that three nucleoside phosphates are required to specify each amino acid in a protein. The transcription sequence is this: DNA makes RNA; several kinds of RNA make proteins—in particular, enzymes; and enzymes govern the

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FIGURE 1.—Schematic illustration of a short section of the Watson-Crick model of DNA. The two helical strands can be seen running vertically, in opposite directions, on the right and left sides of the figure. As the detailed inset shows, the strands are connected by pairs of bases, chosen from the four bases adenine (A), cytosine (C), guanine (G), and thymine (T). The strands themselves are made of sugars (S) and phosphates (P). A combination of a base and a sugar (e.g., A–S) is called a nucleoside; a combination of a base, a sugar, and a phosphate (e.g., A–S–P) is known as a nucleoside phosphate. Thus, the DNA molecule can be considered to be constructed of a linear sequence of nucleoside phosphates. The sequence of bases (e.g., along the left strand of the inset TCAG) specifies the genetic code.

metabolism of the cell. In this way, the nucleic acids control the form and functions of all cells.

With geological time available for the origin of life, the key event may then have been the spontaneous production of nucleoside phosphates in the primitive environment. In contemporary cells, these building blocks join together in the presence of special enzymes which speed their rate of reaction; but given enough time, it is possible that nucleoside phosphates will spontaneously polymerize to nucleic acids.

How might such nucleoside phosphates have originated, billions of years ago, on the primitive Earth? There are very good reasons for believing that the primitive atmosphere of the Earth contained large amounts of hydrogen, the most abundant element in the universe. Some 4 billion years ago, the atmosphere should have consisted primarily of hydrogen and the hydrogen-rich gases methane, ammonia, and water. The transition from this primitive atmosphere to our present oxidizing one is due in part to the escape of hydrogen into interplanetary space, and in part to the production of oxygen by plant photosynthesis. In 1953, Stanley Miller and Harold Urey applied an electric spark—lightning on a smaller scale—to a mixture of gases resembling the primitive atmosphere of the Earth. They produced a variety of amino acids, the building blocks of proteins. Since these pioneering experiments, other scientists have produced other organic molecules—cyanides, aldehydes, hydrocarbons—in simulated primitive atmospheres. In addition to electrical discharges, other energy sources available on the early Earth, such as ultraviolet light and high temperatures, have been utilized.

In later experiments, the amino acids and other simple products have themselves been used as starting points in the production of more complex organic molecules—polypeptides, resembling simple proteins; sugars; and the kinds of bases found in nucleosides. It is a curious fact that these bases absorb ultraviolet light at just those wavelengths transmitted, in the absence of ozone, by the primitive terrestrial atmosphere. For this reason, Cyril Ponnamperuma, Ruth Mariner, and I last year irradiated dilute solutions of bases, sugars, and phosphorus compounds, and found that we had made in high yield various nucleosides and nucleoside phosphates. One of these was adenosine triphosphate (ATP). It is not only the most important energy-storage molecule in plants and animals; ATP is also an RNA precursor, and differs in only one atom from an important building block of DNA. From experiments such as these, it can be estimated that the amount of organic matter produced from natural energy sources in early times is so large that, if dissolved in the present oceans, it would make about a 1 percent organic solution.

Here, then, is a picture of the early stages of the origin of life. Ultraviolet light, lightning, or other forms of energy produce sugars

and bases in the primitive oceans. Under continued ultraviolet irradiation, they combine with phosphorus compounds already in the oceans to form nucleoside phosphates. In turn, the eventual interaction of nucleoside phosphates yields nucleic acids resembling DNA. Because of their characteristic chemical structure, the nucleic acids slowly replicate—that is, they begin forcing the production of other, identical nucleic acids from adjacent building blocks in the primitive oceans.

Occasionally, an error in replication occurs, yielding different varieties of the original nucleic acid molecule. These varieties, however, also reproduce themselves. Some of these new molecules may replicate more rapidly or more efficiently, and they prosper; others do not. Thus, a kind of evolution begins, a natural selection on the molecular level. When, in time, nucleic acid molecules developed which weakly controlled chemical reactions outside themselves, the chain of life from molecule to man began. The critical event has been the production of the first molecule which could reproduce itself.

This picture provides a convenient scaffolding for draping our ideas, but there are many problems which remain to be answered. Will enough nucleoside phosphates be produced, and interact, in primitive times, to form many nucleic acids? How did early nucleic acids control their environment, in the absence of the elaborate contemporary DNA-RNA-protein transcription apparatus? What is the effect of molecular contaminants on the course of prebiological organic chemistry? What is the origin of the cell?

Despite the many uncertainties remaining, certain features of the origin of life are now becoming clear. It is a remarkable fact that the physics and chemistry of the primitive terrestrial environment were such that large numbers of organic molecules were produced—organic molecules which today are intricately entwined in the fabric of life. This has two implications for the possibility of extraterrestrial life. First, the origin of life may be a highly probable event arising by the operation of very general energy sources on very common primitive planetary environments. Second, fundamental extraterrestrial biochemistry may be of a familiar type, even if extraterrestrial morphology and physiology are not.

Although all the planets may have started with similar primitive environments, it is clear that subsequent planetary development has produced a diversity of extraterrestrial environments. The Harvard paleontologist George Gaylord Simpson has emphasized that evolution is an opportunistic, and not a far-sighted, process. Adaptations occur to immediate environmental crises, and not because of any long-term plans. Each evolutionary step must build on the previous ones, and the number of evolutionary "decisions" in the ancestry of any organism is enormous. Thus, we must not expect the inhabitants of

these diverse planetary environments—if, indeed, there are inhabitants—to have familiar forms. They have made other adaptations to other environments. But the anticipated diversity and unfamiliarity of extraterrestrial organisms provide a profound challenge and a supreme opportunity for biologists.

What, then, are our neighbors in the solar system like? What are these planetary environments?

Mercury and the moon are similar in many ways: little or no atmosphere, no surface water or other likely solvents, and extremes of temperature. With no atmosphere, the moon receives intense ultraviolet radiation and proton bombardment from the sun, and no terrestrial organism could survive, unprotected, on the lunar surface for more than a few hours. But conditions are much milder below the lunar surface. Here, there is no solar radiation, the temperature variations are small, at some depths the average temperature is mild, and there may be liquid water trapped below a layer of permafrost. Nevertheless, the likelihood of subsurface life on the moon seems remote, because in the absence of sunlight there is no convenient energy source for living systems.

The planet Venus emits radio waves characteristic of a body at a temperature of 600 or 700° F. Until recently, however, no one knew for certain whether this high-temperature emission came from the surface of the planet, or from some region high in its atmosphere. The voyage of the NASA space vehicle Mariner II to the vicinity of Venus, in 1962, helped solve this problem. Aboard Mariner was a sensitive radiometer designed by five scientists, including A. E. Lilley of the Harvard College Observatory, which radioed back to Earth the news that the radio emission arises from the surface of Venus. The planet is therefore too hot for any familiar biochemicals, and a terrestrial organism placed there would fry. Indigenous life on Venus is very unlikely.

Between Mars, of which we will speak presently, and Jupiter are fragments of stone and rock known as the asteroids. Chips off the asteroids occasionally intercept the orbit of the Earth, and fall to its surface as meteorites. Meteorites are the only samples of extraterrestrial material now available for laboratory analysis. A few meteorites, known as the carbonaceous chondrites, contain a few percent of very complex organic matter. It is not known whether this organic matter was produced in the absence of life, by chemical processes similar to those invoked for the origin of life on Earth, or whether—more interestingly, but less likely—it was produced by living organisms on the parent bodies of the chondrites. Inclusions which superficially resemble microorganisms have also been found in these meteorites. But some have been shown to be inorganic, and others, to result from Earthly contamination—for example, by rag-

weed pollen. It is not known, however, whether all the inclusions can be similarly explained away. There is no evidence for viable microorganisms in meteorites.

At first sight, the Jovian planets (Jupiter, Saturn, Uranus, and Neptune) seem far too hostile to support life. Their measured temperatures range to several hundred degrees below zero Fahrenheit, and their atmospheres are mixtures of methane, ammonia, and other ordinarily poisonous gases. The low temperatures, however, refer to the top of the visible cloud layers on these planets; as on Earth, the temperatures should be much higher below the clouds. Furthermore, rather than being unambiguously poisonous, the atmospheres of the Jovian planets are similar to the primitive atmosphere of the Earth in which living organisms first arose. Even today, there are many microorganisms which do well in hydrogen-rich, anaerobic environments. It has recently been shown that water condensation is to be expected at moderate temperatures below the visible cloud layers. Organic molecules are likely being synthesized today, by ultraviolet light and electrical discharges, in the Jovian atmospheres. The amounts of organic material probably produced there over the last 5 billion years are enormous. The Jovian planets may eventually prove to be immense and invaluable planetary laboratories on the origins of life.

The most Earthlike of the other planets in our solar system is Mars. There is a detectable atmosphere, composed mainly of nitrogen and carbon dioxide and smaller amounts of water vapor. The polar ice caps wax and wane with the seasons, so that the amount of water vapor in the atmosphere varies with time and place. The highest temperatures measured on Mars are about 80° F.; but every night, the temperature falls 150° or so, and the average over the entire planet is about 40° below zero. To round things out, there is no detectable oxygen and ozone, and solar ultraviolet radiation harmful to terrestrial organisms may reach the surface.

Tentative identifications have been made of very small amounts of nitrogen dioxide (NO_2) on Mars. Since large amounts of NO_2 are injurious to many familiar organisms, a few scientists have concluded that life on Mars is impossible. It is of interest to note that the amount of NO_2 in the air of smog-filled Los Angeles often exceeds the amount on Mars. Life in Los Angeles may be difficult, but it is not yet impossible.

Freezing kills in two ways: it produces ice crystals which disrupt cellular structure, and it makes liquid water unavailable, an effect especially deleterious in microorganisms. Food technologists have long known, however, that microorganisms can survive freeze-thaw cycles comparable to those on Mars. Recently, a number of laboratories have tested the survival and growth of terrestrial microorga-

nisms in a more completely simulated Martian environment. Two of my colleagues and I have found that in every sample of soil tested, some microorganisms could survive indefinitely the apparent rigors of the Martian environment. Other experimenters have observed that when a more plentiful supply of water is assumed (such as may occur at the edge of the retreating polar ice caps), many soil organisms grow and reproduce.

If biologically tractable mechanisms exist for the survival of terrestrial microorganisms, what may we not expect of the indigenous biology? We are almost entirely ignorant of the availability of water in the Martian subsurface, and this remains the chief uncertainty in assessing the possibility of life there. Nighttime ice crystallization of tissue water would preclude the existence of larger plants and animals on Mars; but one can envision a variety of adaptations to circumvent this difficulty. It seems premature to exclude, at the present time, the presence of large organisms on Mars.

These experiments also underscore the necessity for sterilization of space vehicles intended for Mars landings. Suppose an unsterilized space vehicle landed on Mars and the terrestrial microbiological contaminants which it contained then proliferated. If, several years later, a life-detection experiment finds Mars populated with microorganisms of a familiar type, what shall we conclude? That the evolution of life on Mars paralleled that on Earth? That biological contact between Mars and Earth had occurred in earlier times? Or that the previous space vehicle had not been sterilized?

Of the other planets in our solar system, serious direct evidence for indigenous life exists only for Mars. That any evidence should exist at all is in itself remarkable, a fact which perhaps can best be appreciated by considering the circumstances reversed. Imagine that we are situated on Mars, and provided with the same level of astronomical instrumentation which exists on Earth today. Is there life on Earth?

The largest engineering works would be invisible. In 100,000 Tiros photographs of Earth, of higher quality than could be obtained with a 200-inch telescope from Mars, only one image showed any sign of the works of man. Lights from large cities, such as Los Angeles, would be marginally detectable, and interpretation would not be easy. Seasonal color changes of deciduous forests and of crops—for example, in the American midwest, or in the Ukraine—would be observed, but here there would arise vexing questions on the reliability of Martian color vision, and the chromatic aberration of telescopes.

Occasionally, bright flashes of light might be discernible. Their durations would be only several seconds, and there would be some evidence of their recurrence only in a few restricted locales, such as Eniwetok and Novaya Zemlya. It is doubtful whether they would be considered evidence for life on Earth—much less, intelligent life.

If the hypothetical Martians had radio reception equipment, and chose to scan Earth in narrow wave bands, they would certainly be rewarded—if that is the word—by television transmission from Earth. There would be an intensity maximum when the North American continent faced Mars, and it would perhaps be possible to determine that this radio frequency emission was not entirely random noise. But barring such observations, the problem of life on Earth would remain an open question.

What evidence, then, do we have for life on Mars? The green coloration and rectilinear markings on Mars were once interpreted, respectively, as vegetation and the artificial waterways of intelligent beings. It is now known that the dominant color of the dark areas of Mars is gray, not green, and that the so-called "canals" resolve, under the best seeing conditions, into disconnected fine detail.

There are, however, more reliable observations which may be indicative of life on Mars. As the polar ice caps recede each year, releasing water vapor into the Martian atmosphere, a wave of darkening proceeds from the polar regions toward the dark areas near the equator. The edges of the dark areas sharpen and delicate pastels of brown, green, and blue appear. There is no doubt about the darkening, but some dispute exists about the reality of the color changes. The biological interpretation of these phenomena is this: the Martian dark areas are covered with organisms, perhaps plants, whose metabolism is sensitive to the availability of water. During most of the year they are in a dormant state. As the wave front of water from the vaporizing polar cap arrives, the organisms grow rapidly and proliferate. The changes in darkness and color of the dark areas can be attributed to these metabolic activities. As the water vapor wave front passes, the organisms once again fall into dormancy.

It has also been proposed that the Martian dark areas are covered with crystals which change their color and darkness when the availability of water increases. The polarimetric evidence, however, shows that the dark areas cannot contain large amounts of such crystals.

Analysis of the polarization of light reflected from Mars indicates that the dark areas are covered with fine dark grains which change in size and darkness with the seasons. These particles could be organisms which grow to maximum size and proliferate as the wave front of water arrives. But it may also be possible that the polarization changes can be explained by a redistribution of sizes of inorganic grains. Perhaps winds which accompany the water vapor front disturb the surface dust, which in the absence of winds has settled with the very large and very small particles deepest.

When the Martian dark areas are observed with an infrared spectrometer, three features are observed which are possibly produced by the absorption of infrared radiation by organic molecules. The

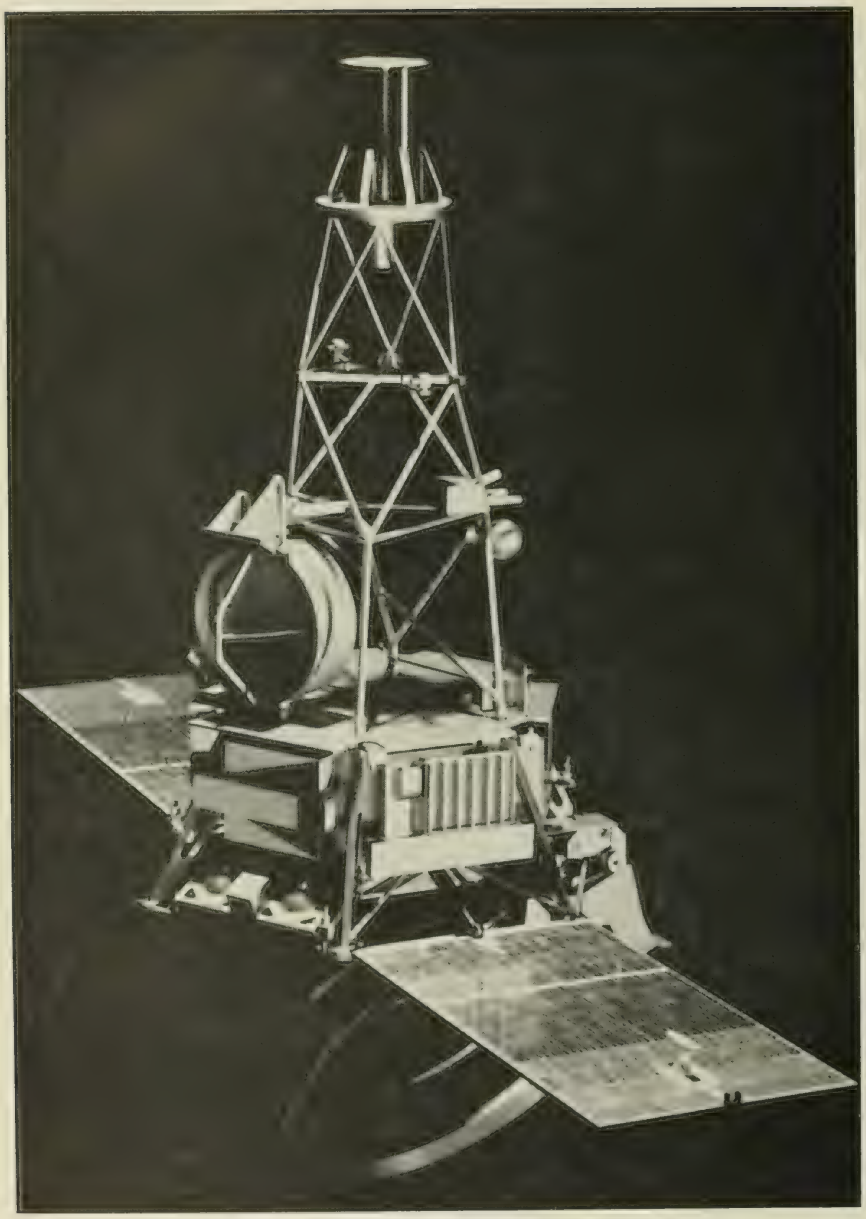
wavelengths at which these features are observed are specific for hydrocarbons and aldehydes; and no reasonable inorganic materials absorb at these wavelengths. The presence of hydrocarbons and aldehydes on Mars may provide a key to Martian biochemistry, but it is also possible—if less likely—that they are irrelevant to the question of life on Mars. We have already seen that complex organic molecules can be formed in the absence of living systems.

While none of the pieces of evidence is convincing by itself, together they are suggestive of at least simple life forms on Mars, composed of familiar organic substances, dependent upon water, proliferating in the springtime, and covering a major fraction of the planetary surface. But we are far from sure.

So we must, after all, go to Mars. The plans are already being formulated, both in the United States and in the Soviet Union, for these voyages of discovery and high scientific adventure which may, perhaps, begin before the decade is out. Instruments have been designed, prototypes built and tested, to land in preselected locales, search for the presence of life, and radio the news back to Earth. Television cameras will see what there is to see—perhaps only sand dunes, but perhaps . . . foliage? . . . fossils? . . . footprints? Coupled with microscopes, they will seek out microorganisms. Culture media will be automatically inoculated with soil samples, and then monitored. Do Martian organisms eat terrestrial foodstuffs?

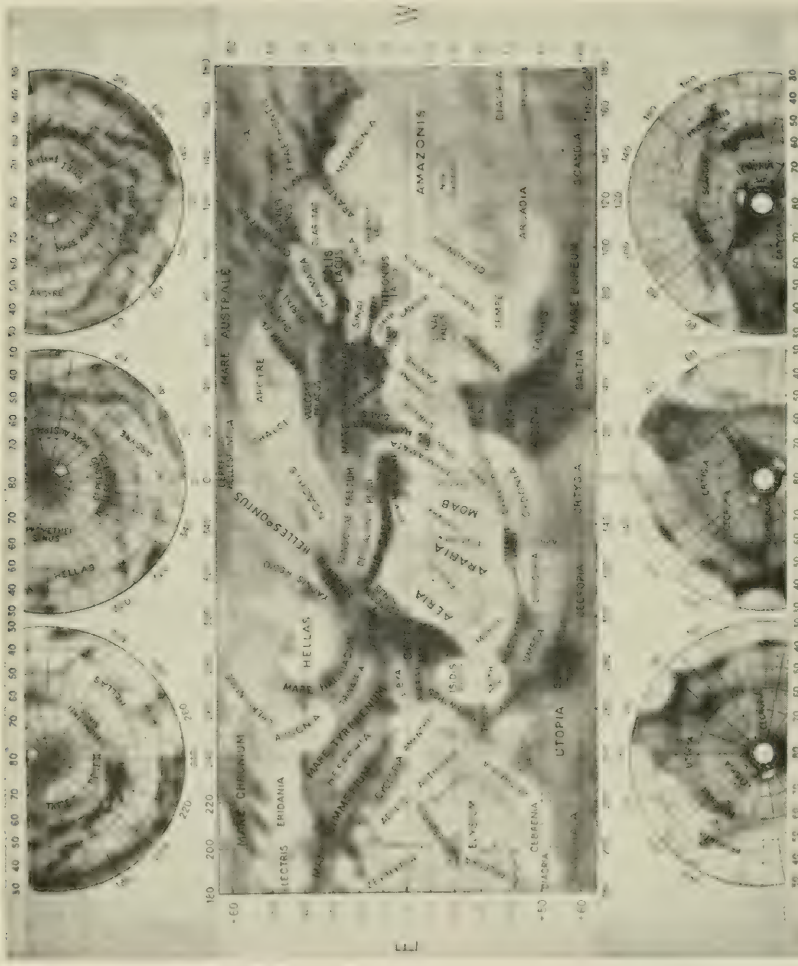
In various forms, life has existed on the planet Earth for some 4 billion years. Thus, on a random basis, the probability of being alive during just that decade when the first definitive study is made of life beyond the Earth is about one-millionth of a percent. To seek the beings of other worlds is the rarest of adventures—an adventure we will all be fortunate enough to share.

A three-dimensional model of a short section of the DNA molecule. Here, each atom of hydrogen, carbon, nitrogen, oxygen, and phosphorus is represented by a different-colored or -shaped atom. (Courtesy of Professor Paul M. Doty, Harvard University.)



The Mariner II spacecraft, as it might have looked during its encounter with Venus on December 14, 1962. The horizontal panels are solar cells for the conversion of sunlight into electricity. The microwave radiometer is the dish-shaped instrument above the solar cells, in the middle of the spacecraft. (Courtesy of the National Aeronautics and Space Administration.)

Photograph of the planet Jupiter, taken with the 200-inch telescope. Most of the observed features are due to atmospheric and cloud phenomena. The solid surface of Jupiter lies far below the clouds visible in this photograph. Toward the upper left corner of the picture can be seen the Great Red Spot, an apparently permanent feature of unknown composition and origin. (Courtesy of Mt. Wilson and Palomar Observatories.)



The International Astronomical Union map of Mars. The bright areas are deserts; the polar caps are composed of ice. The dark areas are the sites of suspected biological activity. Secular changes in topography are observed, e.g., in Solis Lacus, at 90° longitude, −30° latitude. Evidence for organic matter and seasonal polarization changes exists, e.g., for Syrtis Major, at 290° longitude, +10° latitude. These sites are targets for eventual investigation by space vehicles.

The Secret of Stonehenge[1]

By Gerald S. Hawkins

Astronomer, Smithsonian Astrophysical Observatory; Research Associate, Harvard College Observatory; Chairman, Department of Astronomy, Boston University; Director, Boston University Observatory

[With one plate]

A few months ago the book of Stonehenge seemed closed. It was thought that little more could ever be learned about the mysterious stone structure on England's Salisbury Plain. The fraternity of diggers—archeologists and other students of the past—had fixed the dates of construction, from 2000 to 1500 B.C., and the probable methods. Shaping the great stones could have been done by fire, water, and much pounding. Sturdy English schoolboys proved by toil and sweat that cement blocks as big as Stonehenge stones could be floated by raft and rolled overland from quarries as far away as Wales. (Legend said the slabs were brought from Africa to Ireland by giants, and whisked over to England by Merlin's "word of power.") The 50-ton uprights of the trilithons (three-stone archways) could have been tilted into retaining holes. Finally, the 6-ton crosspieces could have been levered up on timber towers.

But *why* was Stonehenge built?

Buried bones indicated that it had been a mortuary, also a crematorium, and it almost certainly was a temple, though not necessarily Druid. But was it more? The unique monument, which Henry James said "stands as lonely in history as it does on the great plain," guarded its secrets well. . . .

I first became interested in Stonehenge in 1954, when I went to the Larkhill missile-testing base nearby. (Of course, we took pains to aim our missiles away from Stonehenge—we were horrified to hear that during World War I an airstrip commander, and a British one at that, had requested that for his planes' convenience the Stonehenge megaliths be flattened. Request denied.) I used to visit that gaunt ruin whenever I could. Even when it was alive and loud with tourists

[1] Reprinted by permission from *Harper's Magazine*, June 1964.

it seemed remote, timeless, brooding. I poked around, marveled, and read everything I could find about it.

The word that originally struck me in the literature was "coincidence." The one thing that all laymen know about Stonehenge—that if you stand in the center on a clear Midsummer morning (around the summer solstice, June 22) and look down "the avenue" you will see the sun rise almost exactly over the distant "heelstone"—was called a coincidence by most archeologists. Beware, it leads to "fruitless conjecture," warned one authority. As an astronomer I could not help feeling that such an alinement of the most important direction of the structure with the point of sunrise of the longest day of the year might well have been deliberate. I wondered.

Then, early in 1961, I had occasion to mention Stonehenge in my book *Splendor in the Sky:*

> . . . If the axis of the temple had been chosen at random the probability of selecting this point by accident would be less than one in five hundred. Now if the builders of Stonehenge had wished simply to mark the sunrise they needed no more than two stones. Yet hundreds of tons of volcanic rock were carved and placed in position. . . . It must have been the focal point for ancient Britons. . . . The stone blocks are mute, but perhaps some day, by a chance discovery, we will learn their secrets.

As I wrote those words, the thought that had been nebulous in my head for some 7 years suddenly crystallized: something should be done. So that summer I went there again, and my wife and I stalked the Stonehenge sunrise. We made base camp in an Amesbury hotel close by, and a few days before Midsummer (alas, we couldn't be there on The Day itself), we went over. Not without overtones of light comedy: sunrise was due about 4:30 (daylight time); we had neglected to tell the hotel we would be going out so early, and we hadn't paid our bill; so with exceeding furtiveness we tiptoed down the long dark hall, past the loudly ticking grandfather clock, and we started our car quietly.

Stonehenge stood black against the lightening sky. I climbed the barbed wire fence (which defeated my wife), placed myself at the center of the circles,[2] and made ready my 8-millimeter telephoto movie camera. And suddenly, there it was—the first red flash of the sun, rising just one-half a diameter to the right of the heelstone. For a moment I was lost in time, bemused, trying to go back 3,500 years to those other sunrises, similarly witnessed by what other people, for what other purpose? But quickly I returned to the 20th century, because I felt surrounded by questions calling out for answer: Why

[2] The inner circle consists of five trilithons set in a horseshoe pattern; the next, traditionally called the Sarcen (Saracen?) circle, is a ring of upright boulders, some with lintels on the top; the outer or Aubrey circle (named for the 17th-century investigator John Aubrey) is marked by 56 equally spaced holes and mounds.

is the heelstone ever so slightly out of line, so that to see it through the trilithon arch you must stand 6 inches to the left of the center of the circles? Why are those trilithon arches so narrow? The huge uprights stand 20 feet high, but the space between is less than a foot. Why do these spaces line up? What do those alinements point to?

As an astronomer, I thought, "Aha! A transit instrument. These arches were used to point to stars or planets or different things in the sky."

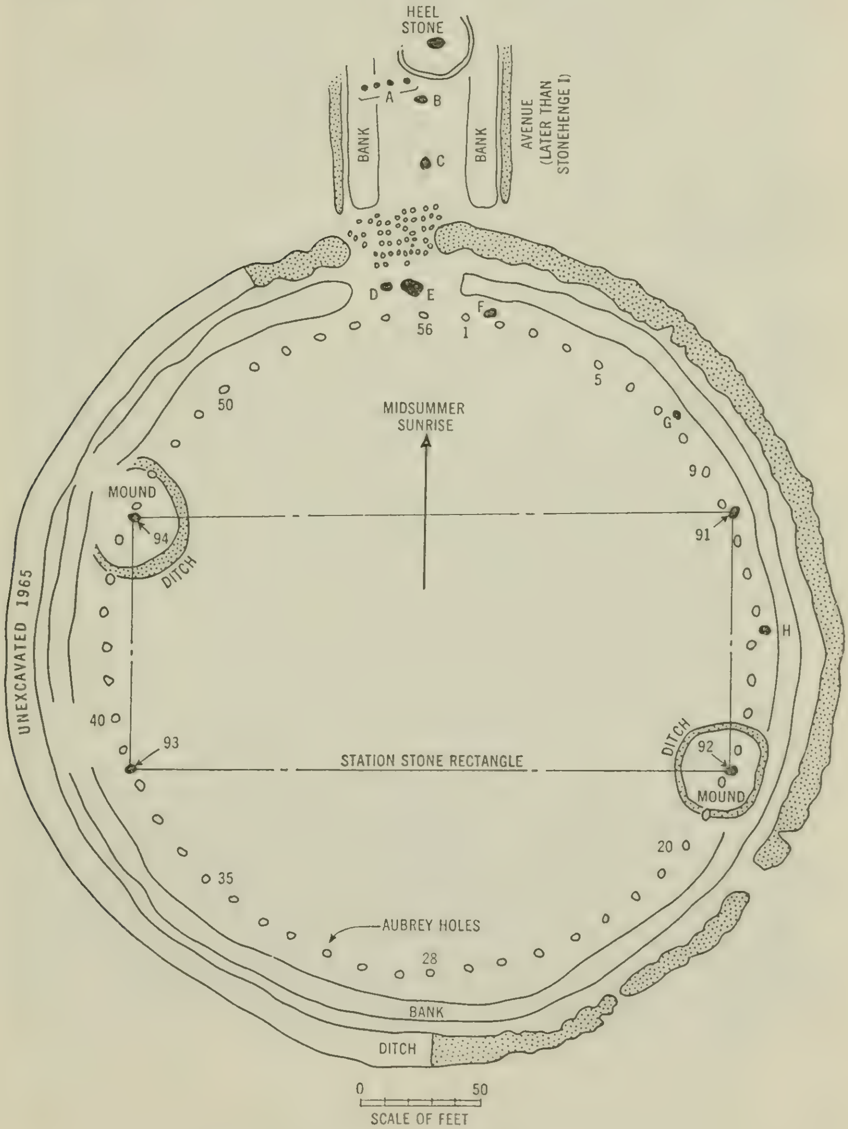


FIGURE 1.—Schematic plan of Stonehenge.

And as I pondered, the sun kept rising. And it was rising almost horizontally, so that it had traveled fully 2 degrees before the disk stood clear of the horizon. That meant that it would be—would have been—extremely difficult to estimate the exact spot at which it lifted clear of the horizon. Clouds, of course, are common in England, and the Stonehenge people were probably no more fortunate than the modern Briton. Nowadays I think only one in five Midsummer sunrises at Stonehenge is clear. All of these things would make the setting of the stones difficult. Critical conditions, devices capable of precise measurement, evidence of knowledge, skill, purpose—*all for what?*

I thought, in that lonely place: "Was Stonehenge an observatory?"

There seemed to be significance in those delicate alinements, and it would most logically be astronomical significance. What would you line sighting-stones on? Surely on the heavenly bodies—the gods of prehistory and so-called barbarism. The center-heelstone certainly pointed to Midsummer sunrise; could there have been other such alinements, such as a corresponding one pointing to Midwinter sunset? I read at Stonehenge that the noted British archeologist R. S. Newall had suggested that possibility, but there had been no verification. What *did* those alinements point to?

I said to myself, "It's no good just talking. The problem is too complicated. We need precise measurement, more elaborate calculation that I am prepared to do. We need the machine." But at that moment, I had more mundane problems to face—the barbed wire fence, the hotel bill, and an English summer squall that was dashing cold rain across the plain.

WHAT THE COMPUTER SAID

Before I left England I got plans and charts of the site. Back in Cambridge, Mass., I armed myself with all the pertinent material in Harvard's Widener Library. I defined the problem: *What, if any, correlation is there between Stonehenge alinements and the rise or set points of any heavenly bodies, as of the period 2000–1500 B.C.?* Then with the help of Shoshana Rosenthal and Judy Copeland at the Smithsonian Astrophysical Observatory, I went to the machines.

First we put charts of Stonehenge into "Oscar," a plotting machine that transforms positions into X, Y coordinates on punched cards. Then we fed those coordinates into the Harvard-Smithsonian IBM 7090 computer and asked it to calculate azimuths, or compass directions, determined by some 170 pairs of positions, a position being a stone, stone hole, mound, archway, or the center. Next we asked the machine to translate those azimuths into declinations, that is, to determine the "latitudes" of the celestial sphere they intersected.

Midsummer sunrise at Stonehenge. (Photograph published by courtesy of the British Ministry of Public Building and Works.)

Then we examined those declinations, the horizon spots to which the Stonehenge pairs pointed. Was there any pattern to them? Did the pairs point to significant rise or set positions of celestial bodies? A quick check showed no significant matching with planets or with the bigger stars, Sirius, Canopus, Arcturus, Betelgeuse, Spica, Vega. . . .

But the most cursory naked-eye glance at those declinations told us of probable sun correlation. The figures +24 and −24 were frequent—and those figures are the declination of the sun at Midsummer and Midwinter, its farthest north and south.

I was somewhat prepared for such solar correlation. Indeed, I had suspected it. But what we next discovered took us by surprise: even more frequently than the ±24 of the sun, the ±29 and ±19 of the moon appeared. The moon has a more complicated relative motion than the sun. During a 9-year cycle its maximum north and south declination moves from 19 to 29 degrees. The machine's finding seemed to show that not only was Stonehenge alined to the sun—it was also oriented to the moon.

I must admit that it was with some unscientific emotion that we programed the machine to take the sun and moon back to 1500 B.C., to get an accurate check of those azimuth alinements. What we found was beyond expectation. To a mean accuracy of 1 degree there were 10 sun correlations. To a mean accuracy of 1.5 degrees, there were 14 moon correlations.

We did the work in spare moments over the course of a year. About 10 hours were spent measuring the charts, about 20 hours were spent preparing the machine program, and the final run on the Harvard-Smithsonian IBM 7090 computing machine took about 1 minute.

It is important to note that *all* of the 24 alinements are between key positions—the center of the structure, the "avenue" or most important axis, the great trilithon arches, the rectangle of "stations," the uniquely placed stones near the entrance. Every one of these key positions paired with others to point to a sun or moon rise or set. That solidly establishes the fact that those alinements were significant, deliberate, basic in the construction. Stonehenge lived by the sun and moon. Could it possibly have been coincidence? Bernouilli's theorem of probability indicates that there is less than one chance in a hundred million that this could happen without a prearranged design.

And what does it mean? It means that Stonehenge was an astronomical observatory. And a good one, too. It could have formed a reliable calendar to predict change of seasons. It could also have signaled danger periods for eclipses of the sun or moon. It could have formed a dramatic setting for observation of the interchange between the sun—dominator of summer—and the moon—ruler of the winter. How it actually *was* used we may never know. All that we can now state with certainty is that it was designed, with astonishing

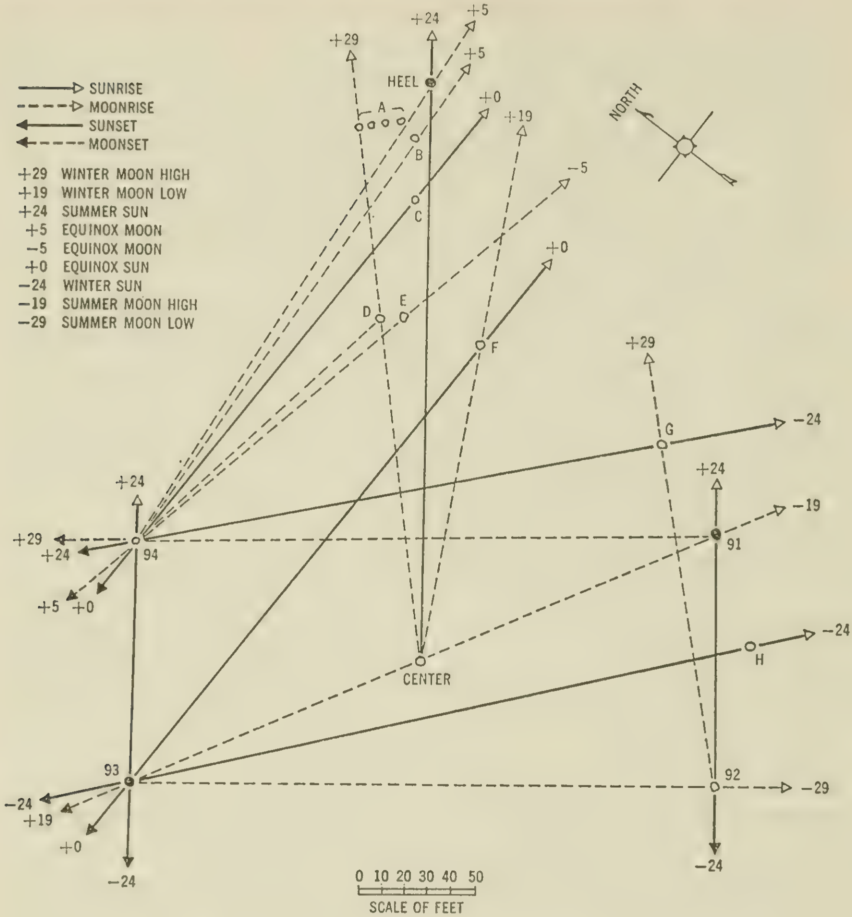


FIGURE 2.—The sun and moon alinements found for Stonehenge.

skill, as an observatory, and that it could have been used for many astronomic purposes.

It is now the responsibility of archeology to digest this new information and from it draw new historic conclusions.

WHAT THE ARCHEOLOGIST SAID

I first published an account of my discovery in the British magazine *Nature*, last October. There has been a surprising amount of response. Newspapers and other magazines from many countries have commented, from England and Canada to Spain and South Africa. Among the letters I have received from archeologists was one, particularly engaging, from R. S. Newall in England:

> It is always difficult, I suppose, when two different sciences meet (if archeology can be called a science), to come to agreement. Astronomers

> have their eyes in the sky; archeologists in the earth. . . . However, I agree that Stonehenge is oriented to the winter solstice setting sun in the great central trilithon as seen from the center or anywhere else on the axis, and since the plan of Stonehenge is sepulchral, it is in some way the mortuary temple to the sun in his old age when he goes down to the lower world at the end of the year or life. . . .

Mr. Newall also wondered if Stonehenge could aline to an astronomic point, the point of sunrise at equinox. He was right; two of the main stoneholes do this to within one-tenth of a degree. The alinement was overlooked by me, I regret to say, and the machine is blameless. Finally he quoted the first-century B.C. writer Diodorus, who said that in the mysterious northern island of "Hyperborea" there was a "spherical temple" to Apollo, and "the god visits the island every 19 years, the period in which the return of the stars to the same place in heaven is accomplished. . . ."

The archeologist concluded: "Now I do *not* say that that refers to Stonehenge, but could it . . . ? Could the full moon do something spectacular once every 19 years at Stonehenge?"

It is a fact that some Jewish and Chinese calendars used a 19-year cycle, and that the Greek Meton knew that the full moon occurs exactly on the same calendar date after a lapse of 19 years. But I was struck by Newall's wonderment about the moon at Stonehenge. I thought, "What about eclipses, at the most spectacular place—over the heelstone?" So I looked up eclipse records for some 150 years. Moon eclipses in December–January, the approximate time when the eclipsed moon would rise over the heelstone, occurred mostly at intervals of 19 years, with sometimes an interval of 18 or 8. Interesting?

A similar condition occurs at Midsummer, and this phase of the Stonehenge cycle is going to happen in 1964, this very month! [3] The full moon is eclipsed at 2 a.m. on June 25, and then sets in the great trilithon as seen from the center of Stonehenge. The monument will be closed to visitors at that time, unfortunately.

In the course of this investigation, I have found out many other arresting things, indicating avenues for further exploration. The machine, quick, dispassionate, tireless, makes possible much more thorough analysis of such an elaborate problem than humans would care to attempt. A new chapter in the ancient book of Stonehenge now lies open.

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[3] June 1964. [This eclipse, and the Midsummer sunrise, was filmed and shown in "The Mystery of Stonehenge," presented by CBS–TV.]

The Smithsonian's Satellite-Tracking Program: Its History and Organization

PART 3 [1]

By E. Nelson Hayes

Editor-in-chief, Smithsonian Astrophysical Observatory

The United States launched its first artificial earth satellite from Cape Canaveral at 10:48 p.m., eastern standard time, on January 31, 1958. The disappointment and frustration of the preceding months lifted as the Jupiter-C Rocket thrust Satellite 1958 Alpha into an orbit with apogee of 1,573 miles, perigee of 224 miles, and period of 114.8 minutes. The payload, weighing 30.8 pounds, carried experiments to measure cosmic rays and upper atmospheric temperatures, and to detect micrometeors. This first American satellite made possible one of the most important discoveries of the International Geophysical Year (IGY)—the existence of what is now known as the Van Allen radiation belt.

The worldwide Moonwatch network of the Smithsonian Astrophysical Observatory was immediately alerted, and on February 2 teams in Bryan, Tex., and Albuquerque, N. Mex., reported sightings of the object. In the ensuing weeks, predictions were sent to those Baker-Nunn camera installations that were in operation, and on March 18 the station in South Africa made the first photograph of 1958 Alpha; Japan followed with an observation on April 5, and the New Mexico station made observations on April 11, 15, and 18. These observations were in fulfillment of the Observatory's obligations to the IGY. Those responsibilities were defined in a memorandum to Dr. Fred L. Whipple, director of the Observatory, from Hugh Odishaw, executive secretary of the U.S. Committee for the IGY. He specified that the Observatory was to assume "responsibility for optical tracking of all satellite bodies launched by the U.S. that are not sending out radio

[1] Part 1 was published in the Annual Report of the Smithsonian Institution for 1961, pp. 275–322; Part 2 in the Annual Report of the Smithsonian Institution for 1963, pp. 331–357.

tracking signals," and "to promptly forward to NAS and to AGI-WARN all optical observations of all future U.S.S.R. launch satellites received directly which are sufficiently reliable to use in orbit predictions."

These instructions were based on the assumption that the space efforts of the United States and Russia during the IGY would be relatively modest. In fact, however, before the IGY ended, on December 31, 1958, the United States had launched eight satellites, and the Soviet Union three. Together, these objects represented a greater tracking load than had been foreseen, and only the superb instrumentation of the 12 Baker-Nunn camera stations and the highly efficient organization of the more than 200 volunteer Moonwatch teams enabled the Smithsonian to make observations of all of them.

By mid-1958 it became apparent that both national and scientific interests demanded the continuance of the United States space program beyond the end of the IGY. However, no civilian Government agency had the funds, personnel, and desire to carry through the work. As a provisional measure, the IGY was continued on an interim basis as the International Geophysical Cooperation (IGC) and the suggestion made that the National Advisory Committee for Aeronautics (NACA) assume the support of the various components of the IGY tracking program.

Meanwhile, a special committee, appointed by President Eisenhower in 1957 to determine our national objectives and requirements in space, recommended in March 1958 that a civilian agency be created to conduct a full-scale program of space exploration. On July 29, Congress passed a bill creating the National Aeronautics and Space Administration (NASA), and it was this organization that in the succeeding months gradually would bring under its aegis most space activities of the United States.

By late 1958, the Smithsonian Astrophysical Observatory no longer was responsible for tracking every satellite launched. Instead, the National Aeronautics and Space Administration assigned to the Observatory and to other tracking networks responsibility for specific satellites. During the last quarter of the year, the Observatory was formally assigned the tracking of Satellites 1958 Alpha, 1958 $\delta1$, 1958 $\delta2$, and 1958 Epsilon. In addition, it made orbital and ephemeris computations on 1958 $\beta2$ and 1958 Zeta for the purpose of preparing predictions of passages. In the first quarter of 1959, the Observatory was given responsibility for two additional objects, 1959 $\alpha1$ and $\alpha2$ launched on February 17.

The Observatory also had a special assignment from the Army Ballistic Missile Agency (ABMA), which had total responsibility for Explorers IV and V. Explorer V had an unsuccessful launching; but Explorer IV went into orbit on July 26, 1958. Designated Satel-

lite 1958 Epsilon, it had an apogee of 1,380 miles, a perigee of 163, and a period of 110.27 minutes. Its instrumentation, consisting of geiger and scintillation counters and two transmitters, was designed to telemeter to earth new data on the radiation belts. Its radio signals failed on October 6, and the satellite came down on October 23, 1959.

The Observatory had proposed to ABMA in May 1958 that it monitor the two Explorers, and furnish space-time coordinates in a special form adapted to the specific purpose of the experiments carried in the satellites to ensure the ultimate value of the telemetered data. This latter work was to be conducted in conjunction with the tracking operations. Dr. Charles A. Lundquist coordinated the program for ABMA; Dr. G. F. Schilling, for the Somthsonian Astrophysical Observatory.

The first Baker-Nunn photographs of Explorer IV were obtained 34 hours after launch. Within a few days, the Observatory was able to supply ABMA with minute-by-minute positions of the satellite. It also prepared orbital elements on a regular basis throughout the lifetime of the radio transmitter. In all, 130 photographic and 250 Moonwatch observations of the satellite were obtained.

In addition, the contract between the Observatory and ABMA provided that various computer programs be written, particularly a numerical integration program and a differential correction procedure, both based on work done by Dr. Leland Cunningham. This cooperative undertaking proved to be highly successful. Explorer IV was the first satellite for which ephemerides were reproduced in multiple copies and sent in a brief time—a matter of a few days or a week—to all interested parties. This procedure has now become routine.

As for the Observatory, the success of the project reflected the refined skill of the satellite-tracking network, a skill that was to ensure the continuance of the network after the IGC.

MOONWATCH

By early 1958, the Moonwatch network consisted of 230 teams; 121 of them were within the continental United States, 1 in Canada, 13 in South and Central America, 77 in Japan, 5 in Australia, 5 in other islands in the Pacific, 3 on the Asia mainland, and 5 in Africa. During the first quarter of the year, the Observatory received 1,371 observations from the teams; 1,272 of these were of Satellite 1957 Beta, 85 of 1958 Alpha, 8 of 1958 Beta, and 6 of 1958 Gamma. Moonwatch observations since October now totaled 3,141.

These observations were of unique and vital importance, especially since the radio signals from Sputnik I ceased 3 weeks after its launching on October 4, and those from Sputnik II ceased 7 days after it was

placed in orbit on November 3. Moonwatch teams had even been able to sight the faint third component (the nose cone) of Sputnik I. Widely separated teams reported 11 different observations; without these the existence of 1957 $\alpha 3$ might never have been verified.

Under the leadership of Leon Campbell, Jr., Moonwatch was more than fulfilling the expectations of its creators and was demonstrating its ability to provide data of singular scientific significance.

THE MOONWATCH TEAMS

Hundreds of people of widely differing personalities and vocations had responded to the romantic and even adventuresome appeal of Moonwatch. Among professionals who joined were many doctors, dentists, engineers, clergymen, and teachers. Radio hams and photographers were especially attracted to the program. Then there were the scores of housewives, salesmen, clerks, factory workers, and secretaries. Students were particularly responsive and came not only from high school and college levels but from grade school as well. One could even find a watchmaker, an artist, a retired Naval captain, a newspaperman, a railway engineer, a priest, a weatherman, a hotel administrator, and an automobile dealer. And the inmates of a State penitentiary offered to establish a team; difficulties in choosing an acceptable observing site rendered this suggestion impractical.

In all, the teams represented a fine balance between the enthusiasm of the amateur and the skill of the technician. What was most needed, however, and fortunately usually was found, was the ability to get along with people, and, for the leaders, a talent for organizing and inspiring others. Frequently, the pattern was for the engineer or other technical specialist to design new equipment, develop observing techniques, and set up efficient communications, while a clergyman, or teacher, or doctor would arouse and sustain the interest of other members of the team.

That interest was infectious. In many communities, Moonwatch took up where Chautauqua and similar activities of the 19th century left off. Then, Americans had neither radio nor television; people in small towns made many of their own amusements and intellectual pursuits, and brought in outsiders to lecture, teach, and entertain. Today, everybody is likely to stay in his own living room and watch television. Moonwatch drew many people away from such passivity and back into a community activity in which many could participate either directly or indirectly. Even those who were not members of a local Moonwatch team could derive much satisfaction from supporting it.

Additional support came from companies and business firms, which often helped to coordinate the efforts of the teams. One company,

for example, bought the telescopes and supplied the local Moonwatch team with radio and all other necessary equipment. Another instituted a telephone-answering service, so set up in the factory that one could dial a number for satellite information. Every day the tapes were changed, and callers could learn where the satellite was and whether it could be seen locally. The tapes were done in language that everyone could understand. The service started with 1 telephone; before it was through, there were 12 automatic telephone-answering lines. In this way, the entire community became involved in the Moonwatch program. Such companies did not use Moonwatch to advertise their products or services; rather, their motives were good will and a wish to do something for the community.

The greatest impact of Moonwatch was on youth. Indeed, a few teams in the United States were set up and successfully operated entirely by young people.

One team in the Southwest was started by a schoolteacher who instructed a course in general science. The town had a considerable problem of juvenile delinquency, and school officials frowned on any activity that would bring the children together at night. Nevertheless, the teacher persevered in setting up the team, and through it generated sufficient interest in science and in satellite tracking not only to achieve a high technical level but also to absorb profitably the energies of dozens of children who might otherwise have been less well employed. In time, the local high school took part in Moonwatch activities and the team was permitted to build a permanent station on top of the school building. Over a period of years, the incidence of juvenile delinquency sharply declined and the whole community benefited from the project.

In another town, a 79-year-old woman felt the challenge of space and created a Moonwatch team consisting of children and parents who observed side by side. She instilled so much enthusiasm for science among these children that many of them went on to college to major in physics, astronomy, and other sciences. Perhaps the most remarkable aspect of her achievement was that she was totally blind.

At the other extreme were teams primarily manned by academicians. One, for example, drew chiefly from the oceanography staff of a large university. Another team was established by a young professor in a Texas college that had no department of astronomy. The team attained great excellence in its observations; the professor built a larger telescope of his own, and so stimulated interest in both the community and in the college that the latter now has an observatory of professional status.

All of these Moonwatch teams had similar problems involving money, equipment, personnel, observing techniques, and communications with Cambridge. Many of them solved these problems in their

own individual ways; others required assistance from field representatives later sent out by the Observatory.

The Smithsonian had no funds to supply equipment other than M-17 telescopes and the loan of satellite simulators, tape recorders, and a few other items, most of them U.S. Government surplus. Each team, therefore, was required to provide its own means for correct timing of the observations, its own observing site, and other facilities. The Moonwatchers showed great ingenuity in supplying themselves with these necessities.

In all probability, any other arrangement would have proved disastrous. Had the Observatory given money for these purchases, undoubtedly a wholly different type of person would have volunteered for the teams. He would not have been essentially a pioneer; he would not have wanted to devise ways and means of meeting needs. In this respect, the first Moonwatchers resembled the first observers at the Baker-Nunn stations, who also had to pioneer in the development of observing techniques and in the most efficient use of available equipment.

On the other hand, a vital difference between the Moonwatch teams and the Baker-Nunn stations needs to be stressed. Both had to develop techniques to meet individual situations. For the Moonwatch teams, this proved a means of maintaining a lively interest in the program and of taxing the creativity and energy of the participants. The same was also true of the observers at the Baker-Nunn stations during the initial phases of the program. Later, however, the requirement that the Baker-Nunn observations be standardized to a single formula and that a high level of consistent excellence be maintained necessitated the development of strict routines that proved in some instances to be unacceptable to the independent spirit of the observers. This problem had to be faced and solved at the first station chiefs' conference in 1959.

Meanwhile, the Moonwatch network flourished during those early days of satellite tracking. But as the Baker-Nunn network gradually became more and more productive of extremely accurate observations the value of marginal Moonwatch observations became less and less. Consequently, by the middle of 1959 all of the teams were revaluated, and each was assigned a status based on such criteria as its observational record, its potential for valuable contributions to the program, its geographical location, and its organizational and financial stability. Of the 200 teams, 35 were classified as prime-A; 10 as prime-B; 2 as special; 81 as standard; and 36 as reserve. By July, 36 other teams were withdrawn from the program. Thus, when the program went under the auspices of the National Aeronautics and Space Administration on July 1, 1959, there was a total of 164 teams with a membership of approximately 5,000.

The contribution that Moonwatch had made to the IGY and IGC was recognized in a series of awards that were given to teams, individual Moonwatchers, and to sponsors and other individuals who had participated. The awards were in the form of Moonwatch emblem pins, printed certificates, and letters of commendation. By mid-1959, more than 4,000 pins and 8,000 certificates had been awarded, and Moonwatch headquarters in Cambridge had forwarded to the IGY National Committee recommendations for achievement certificates to some 50 Moonwatch teams and for 205 other awards to individuals who had made outstanding contributions. These were duly made.

OBSERVATIONAL ACHIEVEMENTS OF MOONWATCH

What the Observatory required from each Moonwatch team was a message giving the time and position of a satellite during transit over the site. Although these observational data needed to be as accurate as possible, they did not have to be obtained by any particular observing technique so long as the procedures provided data in the right format and the team exercised caution in the choice of methods.

Table 1 lists the number of Moonwatch observations of each satellite launched from October 1957 through June 1959. Some of these observations were quite remarkable achievements, and a number of them provided unique data for research and analysis at Cambridge.

On April 13, 1958, dozens of Moonwatch teams were alerted to observe the demise of Sputnik II. Sightings of the satellite in its descent were made by teams in Millbrook, N.Y.; New Haven, Conn.; and Bryn Athyn, Pa.; final observations were made from ships and islands in the Caribbean as the satellite plunged to its death near the northern coast of South America. This dramatic occurrence was recounted by Dr. Luigi Jacchia in the Observatory's Special Report No. 15.

TABLE 1.—*Moonwatch Observations, October 1957 to June 1959*

Satellite	Number of observations	Satellite	Number of observations
1957 α1	805	1958 δ3	9
1957 α2	61	1958 δ4	1
1957 α3	11	1958 Epsilon	384
1957 Beta	2,389	1958 Zeta	247
1958 Alpha	495	1959 α1	172
1958 β1	49	1959 α2	277
1958 β2	17	1959 Gamma	3
1958 Gamma	59		
1958 δ1	3,855	Total	9,835
1958 δ2	1,001		

Late in October 1958, observations of Satellite 1958 Alpha had fallen off to such an extent that accurate predictions for the Baker-Nunn stations could not be prepared. Consequently, no Baker-Nunn photographs were being made, and the satellite was in danger of being lost. Twenty-five Moonwatch teams in the United States were asked to make a special effort to find the object and were sent rough predictions derived mainly from "best guesses" and extrapolations. Moonwatch observations began to come in again, finally in sufficient number to generate good predictions for the Baker-Nunn stations. Thereafter the satellite was photographed on a regular basis. The "lost" satellite was found.

In May of the same year, Professor Arthur S. Leonard, leader of the Sacramento, Calif., Moonwatch team, derived the orbital elements of the carrier rocket of the first Vanguard satellite from observations obtained at Albuquerque, N. Mex., and at Sacramento. These data were then used by the Observatory to make Baker-Nunn predictions that resulted in photographs of the object on May 11 by the station at Organ Pass, N. Mex., and on May 12 by the station in Hawaii. Confirming visual observations were made by Moonwatch teams in China Lake, Whittier, and Walnut Creek, all in California, on May 11.

One of the most elusive objects was Vanguard I itself, a 6-inch sphere orbiting between 409 and 2,453 miles from the earth. In July, Moonwatch reported that the teams in Yuma, Ariz., and Alamagordo, N. Mex., had observed the satellite passing some 2,000 miles above the earth over a point as much as 1,000 miles south of them. Thereafter, few observations were made of the satellite either by Moonwatch teams or by Baker-Nunn cameras. A special search undertaken by Moonwatch teams in the fall of 1958 failed to locate the satellite. Early the following year, Dr. Henize developed a new search pattern for another attempt. Some 42 Moonwatch teams having special experience and capabilities were selected to participate in the search beginning April 1 and to extend for about 6 weeks. The plan utilized a network of teams in pairs separated north and south about 15 degrees. The basic idea was to find some search area in the meridian plane of the observing teams through which the satellite must pass within some given time interval and to concentrate the search within this area for the required time so as to ensure that the satellite would not slip through the net. Using an observation made on May 6 by the two Moonwatch teams in Albuquerque, N. Mex., Professor Leonard in Sacramento modified the orbital elements of Satellite 1958 $\beta 2$. Using the resulting predictions, his team observed the satellite on May 10. From new predictions several other Moonwatch teams in the West and Southwest were able to observe the satellite, and by May 12 the Baker-Nunn camera stations could once more begin to photo-

graph the object. Thus another satellite was rediscovered by Moonwatch.

When the third Russian satellite (Satellite 1958 Delta) was launched on May 15, 1958, a large number of Moonwatch observations made it possible to determine that the satellite was accompanied by at least three components. On November 21, all Moonwatch teams were alerted to observe the last few revolutions of 1958 $\delta 1$. Many such observations were received, including two made during what is believed to have been the next to last revolution of the satellite; these sightings were by teams in Wichita, Kans., and Albuquerque, N. Mex.

In the late spring of 1958 only three observations were made of Satellite 1958 Epsilon; these were not sufficient for the preparation of predictions for the Baker-Nunn stations. Fifteen Moonwatch teams were assigned to concentrate on this object and a number of observations were made shortly thereafter. The satellite, however, proved to be so erratic that special observations of it were again requested in December. This time, however, Moonwatch was unable to find it.

Within 2 days of the launching on February 17, 1959, of Satellite 1959 $\alpha 1$ (Vanguard II), Moonwatch teams were called upon to determine whether the third stage component of the rocket, Satellite 1958 $\alpha 2$, was in fact in orbit. By the end of the month a number of teams had made observations of the object and from these the Observatory was able to prepare preliminary ephemerides for the Baker-Nunn stations. Subsequent photographs confirmed the existence of the satellite.

These are but a few of the noteworthy achievements of the Moonmatch network during the IGY and the IGC.

BAKER-NUNN CAMERA STATIONS

Explorer I offered the first significant challenge to the capabilities of the Baker-Nunn camera that could reasonably be expected to be met. Satellite 1957 $\alpha 2$ (Sputnik I) had been a 22.8-inch sphere, probably painted black, that during its brief lifetime of 92 days could not be successfully photographed by the only Baker-Nunn camera then in operation, first at South Pasadena, Calif., and then at the Las Cruces station in New Mexico. The rocket case (Satellite 1957 $\alpha 1$) had been a large object visible to the naked eye and easily photographed by the camera. Satellite 1957 Beta consisted of the payload of Sputnik II and the rocket case, which never separated; together they were probably 85 feet long and weighed as much as 4 tons. Again, the satellite was visible to the naked eye and easily photographed.

Satellite 1958 Alpha consisted of a payload 22 inches in diameter and about 10.5 pounds in weight, and a cylinder of approximately 30

pounds; together they formed an object approximately 80 inches in length and 6 inches in diameter. Its rapidly changing orbit required that predictions of its passages be good; its poor visibility required that a camera of exceptional capabilities be used in photographing it. The predictions from Cambridge during the initial days of the satellite's orbiting were not of high quality. In addition, the observers had considerable difficulty in finding the satellite image on the plates; in part, this was due to inexperience and, in part, it was a consequence of the satellite image on the film being quite small.

As predictions were improved and as field procedures were refined, more and more successful photographs were taken of this satellite and of those launched subsequently.

The first Baker-Nunn camera station was established in Las Cruces, N. Mex., and the first photographic observation of Satellite 1957 $\alpha 1$ made there November 26, 1957. There also the first observers were trained to use the camera and related equipment and prepared to man the other stations as soon as possible.

From February through May, those other stations were established, the 2d camera being shipped from California to South Africa on February 3, and the 12th to Hawaii on May 28. The last station to begin photographing satellites was that in India, on August 29, 1958; although the camera had been shipped there on March 30, films could not be taken earlier because of the monsoon season.

As soon as all cameras were in the field, the observers carried out tests, including the making of focus plates to be sent to Cambridge for analysis. The results showed that all cameras, except that in India for which no test films were yet available, yielded image diameters in the center of the field of 60 microns or less, with an average diameter on the order of 35 microns. Differences in focus between the center and the edge of the field of the film indicated the need for further adjustments and possibly for a refiguring of the backup plates in several cameras. However, the image quality of the cameras was good, demonstrating that each of them was capable of photographing the faint United States satellites 1958 Alpha and 1958 Epsilson.

While these tests proved that the cameras were more than adequate to the task for which they had been designed, limited steps were taken during the remainder of the IGY to improve their performance, including visits by Mr. Sydor, the optical specialist of the Observatory, to a number of stations to adjust the optical systems.

One nagging fear had been that the KzFS–2 glass used in the outer elements of the corrector cell of the camera would prove unduly fragile as that glass was sensitive to acid staining and was "soluble" in distilled water. Obviously, it was necessary to protect the glass

from rain. The lens cover, therefore, had to be kept on the corrector cell at all times except during actual photography, and the air-drying system for the camera kept in good working condition. Later, special desiccators would be installed. At each station, however, some highly individual methods were used to ensure that the outer lens was kept dry; at one, the observers found that a quick swipe of the lens with a baby's diaper was highly effective.

In any case, experience proved that although the outer lens was inevitably pockmarked to some extent by moisture in the air, the loss of transmission was very small—not more than 10 percent. Although acceptable, this was not ideal, and later means would be found to protect the lens better.

Another problem was that the camera was "blind" to the observer. In other words, there were no means whereby the observer could see what the camera was photographing. To remedy this situation, late in 1958 the Observatory shipped 5-inch aperture telescopes to the stations. One of these was attached to each camera so that the axes of the two telescopes were parallel. The observer could then watch what the Baker-Nunn camera was photographing and during a transit make any necessary adjustments in the tracking mechanisms so that the image of the satellite would remain roughly centered on the film. This procedure proved to be extremely valuable in directing the camera to photograph newly launched satellites for which predictions might be somewhat inaccurate.

A third difficulty involved the Norrman time standard. In part, this was a consequence of the heavy strain that was placed on the mechanism itself. For example, a transformer proved to be substandard to the needs of the system and had to be replaced in all the clocks. In part, also, it was the result of inadequate power supply to some of the stations. Consequently, the amplifier to the clock had to be modified, and other means found to ensure a constant and steady power.

The film chosen for the camera was the famous ID–2, which provided the spectral distribution needed and was extremely fast. Nevertheless during the remainder of the IGY consideration was given to several other types of film. Early in 1958, Eastman Kodak proposed the use of their S.0.1200 emulsion. Tests at the New Mexico station proved that the film was about twice as fast the ID–2. However, the manufacturer encountered serious production difficulties that prevented production of the film in sufficient quantities. Later that year, one other film was tried: a Dupont emulsion coated on a "cronar" base. It was unsuitable. In addition, tests were made to determine the possibility of photographing very bright satellites during the day by using an infrared-sensitive film together with an infrared filter

over the corrector lens of the camera. These tests did not give very hopeful results.

Meanwhile, the ID–2 film was proving more than satisfactory, and as the number of satellites increased and the skill of the observers improved, it was needed in greater quantities. By early 1959, plans were made to send an additional 20,000 feet of film to each station—enough for 100,000 home snapshots. This amount was based on the assumption that the average weekly use of film was about 1,000 feet.

In addition, each station had to be shipped various other materials to ensure continuous operation. These included not only the usual nuts-and-bolts necessary to the maintenance of any mechanical equipment, but also substantial electronics supplies for the Norrman time standard.

The kinds of problems encountered at the stations can perhaps best be summarized by noting some of the specific difficulties that occurred during the second quarter of 1959.

In Argentina four anchor bolts holding the large diesel engine for the auxiliary power supply broke off because of the inferior quality of the metal. New bolts had to be installed in fresh concrete. One of the bearings of the 15-kilowatt generator was badly scored, and a new one had to be obtained and installed, along with new brushes. The pulley was realined and the generator cleaned. The power was then turned off so that the clock could be reset.

In South Africa the Baker-Nunn mirror seemed loose and the collimation poor. The corrector cell had to be dismantled and sent to the Bureau of Standards in Pretoria for collimation. The mirror was adjusted and cleaned and a new shear-pin unit and clutch were installed. The power amplifier was moved into the camera house and new relays installed. Later the crystal clock ceased to operate and had to be repaired.

In India the film transport system of the camera jammed when operating at 32 seconds per cycle. Both generators were out of order for a week, and the clock lost time at a high rate.

In Peru the Norrman clock gained 2.9 seconds and the power amplifier continued to give trouble. The clock failures during this time were believed to be the result of low-line voltage or earthquakes.

In Curaçao the slave clock stopped because of a failure of a filter condenser in the power amplifier.

These difficulties were of the sort that could be expected, and each was resolved in turn. All of them were part of the operations of each station as they had originally been conceived. When, however, it became evident that the Smithsonian satellite-tracking program would continue after the IGY and the IGC, plans would develop for overall improvement of the system. These included better dehumidification, sealing the interior of the camera house, various additions to station

buildings, and, above all, engineering studies to improve operation of both the camera and the timing system. These and other modifications of the network would be carried out when the program was funded by the National Aeronautics and Space Administration's grant to the Observatory.

Meanwhile, however, the observational achievements of the system were notable. From July through September of 1958—the first quarterly period when all of the stations were operational—the stations reported 480 observations of four satellites: 1958 Alpha, 1958 δ1, 1958 δ2, and 1958 Epsilon. The total for each station was as follows:

New Mexico	71	Peru	86
South Africa	73	Iran	18
Australia	62	Curaçao	47
Spain	40	Florida	14
Japan	44	Argentina	3
India	1	Hawaii	45

During April and May of 1959, shortly before the close of the IGC, the stations recorded the following number of observations:

New Mexico	160	Peru	210
South Africa	79	Iran	68
Australia	237	Curaçao	74
Spain	130	Florida	57
Japan	94	Argentina	86
India	149	Hawaii	105

In part, of course, this large increase was a consequence of the number of satellites in orbit; in part, also, it was the result of vastly improved predictions and observing techniques.

From November 1957 through June 1959, the stations made the total observations shown in table 2.

The outstanding single achievement was photographing the Vanguard experimental sphere (1958 β2). This object, 6 inches in diameter, was filmed at a distance of 2,400 miles, first by the station in Woomera, Australia, and subsequently, at comparable ranges, by several others.

THE STATION OBSERVERS

Originally, the Observatory had determined that two observers at each station would be a sufficient number, although in fact in the very early days usually each station was manned by only one. This meant that the observer had to be an electrician, a mechanic, a maintenance man, a carpenter, a computer, and, of course, an observer. Typically, he made two or three observations a night.

Even when each station was staffed with two men, the increasing load proved to be too much, so that by mid-1958, the Observatory had decided that at least three trained observers were necessary at each station to ensure continuous and efficient operation. As a consequence,

TABLE 2.—*Number of Baker-Nunn Observations (Separated by More Than 8 Minutes) October 1957 thru June 1959*

Satellite	Baker-Nunn Camera Station												Total per satellite
	New Mexico #9001	South Africa #9002	Australia #9003	Spain #9004	Japan #9005	India #9006	Peru #9007	Iran #9008	Curaçao #9009	Florida #9010	Argentina #9011	Hawaii #9012	
1957 α1	3	----	----	----	----	----	----	----	----	----	----	----	3
1958 α1	116	90	109	55	83	102	145	35	67	56	40	116	1, 014
1958 β1	10	31	47	5	2	4	50	3	12	7	12	16	199
1958 β2	27	4	9	11	8	10	15	12	5	14	4	10	129
1958 δ1	14	23	36	35	29	----	18	21	9	9	2	19	215
1958 δ2	67	43	87	80	93	54	50	35	35	18	15	29	606
1958 δ3	----	1	----	----	1	----	----	----	----	----	----	----	2
1958 γ1	3	----	1	----	----	----	----	----	----	5	----	4	13
1958 ε1	34	24	46	39	54	27	34	8	16	5	17	15	319
1958 ζ1	4	6	17	2	10	3	3	----	1	----	2	2	50
1959 α1	123	56	121	66	48	76	103	45	73	60	45	75	891
1959 α2	103	51	120	53	46	44	102	35	71	50	39	71	785
Total per station	504	329	593	346	374	320	520	194	289	224	176	357	4, 226

a recruiting program was initiated to find new men for the job. Inquiries were circulated to astronomical and associated scientific departments of major American colleges and universities, and courtesy notices were placed in various technical publications. The response was slow, and many of those who applied were not suited for the work. Meanwhile, a second observer training program in New Mexico began in late January 1958, with Dr. Henize and Messrs. Burkhead and Ledwith instructing the apprentices. New training sessions continued in the months that followed, so that by July 1959 a total of 82 prospective observers had been instructed in the use of the camera and its related equipment.

The original pattern of personalities and of work at the station was largely set by the character of the first observers. In the early months, running a Baker-Nunn camera station was very much a do-it-yourself project, a one-man project, at best a two-man project. The program demanded, and received, the devoted efforts of men who were willing to work 80 to 100 hours a week.

Enthusiasm was an obvious necessity as were considerable intelligence and an ability to understand and work with mechanical things. Perhaps the most important characteristic required was a sense of humor, for it often proved the buffer against circumstances that might otherwise have been unbearable.

The observers were not theoreticians. Their interest was chiefly applied rather than pure science. Only one of them, Dr. Kozai, was successful both as a tracker of satellites and as an analyzer of data. After a period at the station in Japan, he joined the staff at Cambridge and achieved significant results in the use of observations in studies of the upper atmosphere and of the geopotential.

As additional observers joined the program, the work at each station became more and more a team effort, so that in addition to the minimum level of technical competence, there developed the need for people to work together, and for someone to guide and direct them. From this change emerged the concept of a chief who bore responsibility for the running of the station. Further, there developed necessarily a basic routine for getting things done and at the same time a loss of some of the romantic thrill that had resulted from accomplishing single-handedly the seemingly impossible. This was to result in major changes later in the kind of person needed in the program.

One of the most interesting aspects of the field program was the evolution of a kind of migratory system. Observers moved from one station to another, and often spent some time doing work at headquarters in Cambridge. This crossfertilization was a deliberate effort on the part of the people in Cambridge to make the observers see the program as a whole and to understand the needs at headquarters as well as the needs in the field. As a consequence, there came about a better rapport between the two groups.

Learning in the field was in many ways a unique experience in this day and age. The group had to adjust to an often trying situation, had constantly to be developing new techniques, and to find related or allied interests at the station, such as geology, seismology, and archeology, to occupy their spare time profitably as the workload at the station became less burdensome.

The attitude of the observer toward his job was, of course, of crucial importance. At some stations there tended to be an unhealthy competition among the observers, which led to friction that interfered with the productivity of the group. Frequently there had to be a shakedown period when new observers arrived, a time during which the energies devoted to internal dissension had instead to be directed toward the job at hand.

Yet, there was always a great sense of responsibility among the observers so that in spite of some personal friction and despite the fact that the early staff was small, no station ever went unmanned.

Not only did the observers have to learn to live and work together; they also had to learn to live and work with local people. At a number of stations, the experiences of the nationals with Americans had been limited to military missions and to commercial enterprises. The personnel of the Baker-Nunn camera station proved a refreshing

change. From the beginning, the local people could see what the observers were doing and realize immediately that it had no military connotations, was not intended to make money from them, and had no purposes other than those of peaceful scientific work. There was never anything secret about the optical tracking of satellites.

On the other hand, the actual meaning of the tracking of satellites and the worldwide effort of the IGY were not always readily understood in some communities. The observers had to make an effort, therefore, to reach and teach the people. This they did by giving lectures, contributing equipment and photographs for various shows, inviting local school classes to tour the station, and declaring certain days "open house" at the station so that anyone and everyone could visit. In addition, many observers went into the local communities to help out in whatever ways they could. In some instances this meant the loan of tools or the sending of a truck. In others, it meant setting up of classes to teach English to the people. At the station in Peru the observers helped out greatly after the earthquake of 1959. In Iran, the observers taught hospital personnel how to build and use needed medical equipment, and even constructed an incubator for babies.

Perhaps most important, each station became a center of information about artificial earth satellites, a clearing-house for celestial activity. It was the policy of the Smithsonian and the aim of the observers to have each station function locally in a manner smiliar to that of the Observatory in Cambridge—as a source of public information, as a means of informing people of astronomy and the space program.

From the first, the Observatory encouraged the observers to take their wives and children with them, a policy that served to broaden the contacts between station personnel and the local people, and that added stability to the whole arrangement. The reactions of the wives varied as one would expect. Their attitudes were reflected in a series of round-robin news letters that were issued from 1958 through 1961.

For some of the wives, life at the station proved to be flat, stale, and unprofitable. They seemed to lead lives of constant frustration and fear—frustration because life at a foreign station was not like life in America, and fear because disease and other dangers seemed always to be at hand. These women, of course, failed almost completely to integrate with the local community and to learn from the experience. One of the best symbolic expressions of this failure was the inclusion in one of the news letters of an exotic recipe from *Harper's Bazaar!*

For others, however, it was a richly rewarding experience. The wives not only made pleasant homes for their husbands overseas, but also participated as much as they could in community affairs. They taught in local schools, conducted special adult classes in English,

went on archeological and other field trips with their husbands, learned the local language, and by such means filled their days with activity.

No less a range of response occurred among the observers themselves. Some could hardly wait to return to the United States. Others, working under the happiest of circumstances for themselves, flourished and gained a new kind of education that perhaps would not in those years have been possible in any other way.

As individuals and as families, they learned that entertainment could come without mechanical means, such as radio and TV. The emphasis was on participation. One could not in this situation be a passive individual. He had to take part in the life going on around him if he himself wished to enjoy life. It was, in the words of one observer, "a return to fundamental human relationships."

It could be, and for many was, in every respect a broadening and fascinating experience. The observers and their families began to think "globally." There developed the notion that the world was full of people not unlike themselves. For in spite of differences, the similarities between observers and nationals were overwhelming. And even the differences became less and less as the language barrier was surmounted.

Perhaps what had to be learned was best summarized in a brief essay that Paul Wankowicz wrote while in Iran:

> Persia is a country of melons. They come in all sizes, shapes, and colors, and the supply seems almost inexhaustible.
>
> In Iran, as in the United States, the problem remains the same. The cold, silent outside of the melon tells very little of what you will find inside.
>
> The most common method of determining whether a melon is ripe is the thump system, which entails gently thumping it with your knuckles. If the thump is hollow and resounding the melon is good. If it is hard, with a bell-like sound, then the melon is green. And, of course, if your fingers sink into it, the melon is rotten. Melons tend, however, to vary greatly in their thump quality.
>
> The next method depends on the structural quality of the shell. If you gently squash the melon in the middle it will elongate slightly so that you can feel its springiness. You possibly can develop a feel for the tensile strength of the outside and the compression that the seeds and pith will take on the inside, as well as of the stiffness of the meat between. Of course, slightly later you discover that melons vary according to the region in which they were grown. The melons from villages that skimp on water or have lazy jube diggers tend toward a harder inside. So the tensile-strength analysis does not yield thoroughly satisfactory results.
>
> For the next step, you decide that the condition of the melon can be determined from the little grey patch on the bottom, which has continually rested on the ground. This patch tends to be slightly softer than the rest of the melon because of the moisture that it has picked up from the ground, and the shade in which it has been kept as the melon ripened. If it is too soft the melon is probably over-ripe. If it is too hard, moisture of the ground hasn't had time to work on it, and the melon is probably unripe. But when you have found one

that you think is the king of all melons, you still discover that there are melons that absolutely defy the scientific approach.

After you pass this stage you are considered an expert if you develop the final and fool-proof system. The secret of success and the secret of good melon lunches in Iran is very simple. You walk up to the storekeeper and say: "Give me one good melon please." This roughly runs: "Lotfan yeki harbuse hoob bedi hemen." When he hands it to you you ask him in a rising inflection: "Hoob ast?" which means: "Is it good?" And if you have dealt with him before so he knows that you are a man of the world, then he is sure to give you a delicious melon. This system does not fail!

The intense experience of life at an overseas station, and of tracking satellites, considerably altered everyone who participated in it. The observer was no longer the same man as when he started in the system; similarly, his wife and children had changed. Each had matured in his own individual way. And in general, those who left the project for one reason or another found that their experiences were both culturally and financially profitable.

Yet, a fundamental dilemma still remained. The kinds of people who did the kinds of things that the Observatory wanted in those early months—those who could combine technical knowledge with an ability to work with people—became less and less contented with the situation as the work became increasingly routine and therefore offered fewer and fewer rewards. This was to become a crucial issue at the first station chiefs' conference in mid-1959.

COMMUNICATIONS

In the first half of 1958, generally satisfactory communications were established at all of the tracking stations. A number were linked with Cambridge through the military network and others by commercial wire services and teletype. At that time the possibility of direct radio linkage with certain of the stations was considered, but since the existing system was working efficiently, there did not seem any need for such an arrangement. By March of 1958, the communications center in Cambridge was handling nearly 400,000 words per month.

Inevitably, there were delays of one kind or another; messages were lost; and sometimes the wrong material or information was sent to the stations. At one point, the chief observer at one station sent the following memorandum to headquarters in Cambridge: "We have received the material on 'stuffing' and I might say it will come in handy if we have any more visitors before we get this station into full operation. Since I failed to bring along my aqualung, I feel that it is inadvisable to try collecting invertebrate animals other than insects and molluscs. There are, however, thousands of fossils just a few hundred yards down the hill from the station, so perhaps I'll try my

hand at this operation when I have time." He had been sent by mistake a packet from the Smithsonian U.S. National Museum.

By mid-1958, excellent routines for the exchange of satellite information had been worked out. Tapes were cut and ready for immediate transmission to all stations giving the news that a satellite had been launched.

Another tape was cut stating that the satellite went into orbit at a particular time, and this information was then sent to the station. Following this second message, still another gave all the latest information received on the satellite itself—its size, weight, revolution, perigee, apogee, etc.

There was constant improvement of the system and efforts to overcome annoying delays. By early 1959, the communications center was already beginning to tie into the services of the National Aeronautics and Space Administration. Thus, the teletype services to South Africa were put through NASA facilities, and similar arrangements were being discussed for lines to Australia and Peru. By March, a privately leased teletype line was in operation between the headquarters in Cambridge and the Space Control Center in Washington, D.C.

PHOTOREDUCTION

The first Baker-Nunn films of satellite transits were tediously reduced at the stations, and information on the time and coordinates of the satellite image was rushed to Cambridge by cable. The time shown on the slave clock was, of course, directly photographed on the film. The position of the satellite image was determined in relation to the background of stars. These measurements were sufficiently good for the generation of new predictions of satellite passages and for preliminary estimates of atmospheric density and other phenomena. They did not, however, provide nearly so precise information as the Baker-Nunn camera was capable of offering. In fact, these measurements of position were inaccurate on the average between 60 and 90 seconds of arc, which might represent for a low-orbiting satellite as much as 1,000 feet in space.

There arose, therefore, the necessity for finding a much more accurate, reliable, and rapid means of reducing the films. As early as March 1957, an experimental machine for measuring Baker-Nunn film was constructed; it incorporated a film backup plate similar to that used in the camera so that angular distances could be measured directly. In the ensuing months, however, as construction of the first Baker-Nunn camera was rushed to completion, and then as the first satellites were launched and tracked, this aspect of the program received relatively little attention. It was not until early 1958 that the staff of the Observatory formally outlined the possible equipment and

procedures by which the precise reduction of film might be accomplished.

The objectives of this phase of the work were detailed as follows: (1) to establish means of defining the film images that were measurable and of locating them on the film when they were not apparent to the naked eye; (2) to test the several machines available for the measuring procedures; (3) to select and identify the reference stars in the background; and (4) to estimate satellite magnitudes and variations in brightness.

Procedures were set up for filing and indexing all films received from the Baker-Nunn camera stations and for sending to them preliminary comments on the quality of the films themselves. Each film was searched for satellite images not detected during field reduction. For this purpose, film viewers and binocular microscopes were used. With magnifications of 6.6 × and 20 ×, a film could be scanned in two sweeps, and then the microscope zeroed in on possible satellite images. There was the suggestion that Mr. Nunn design a special blink-microscope for detailed searching of the Baker-Nunn films; this was never built, however, because commercially available microscopes proved wholly adequate to the job.

Two sophisticated machines for measuring positions on the film were chosen for test: the Mann two-screw comparator, and the Van Biesbroeck goniometer. Preliminary estimates suggested that the former might be used on those films that, because of excellent images and favorable distribution of reference stars, might produce the most refined measurements, while the latter would provide sufficient accuracy for run-of-the-mill films. However, before any decision was made, a detailed comparison of the two machines had to be undertaken.

On the Van Biesbroeck photogoniometer the film is stretched to a curvature similar to that at the focal surface of the Baker-Nunn camera. The film is then positioned in a manner similar to that of the strip in the Baker-Nunn camera itself. The plate takes the original orientation with the use of known stars, and the measurer points a microscope to the satellite image. The images are measured with a precision goniometer placed in the center of the curved film. The film holder is shifted toward the goniometer or away from it until the angular distance of the selected stars (about 20 to 25 degrees apart), as measured with the goniometer, satisfactorily approximates the angular distance of these stars in the sky. Then the film holder is moved in until the frame appears in the position in which the film was taken; the horizontal plane corresponds to the celestial equator. The differences in horizontal circular readings now equal the differences in right ascension, and the differences in vertical circular readings equal those in declination.

The differences between the theodolite readings for the satellite and any one of the reference stars give a value for the satellite position. The mean of the values obtained for all the reference stars is accepted for the final position of the satellite. The smallest readable unit on the Van Biesbroeck goniometer is 1 second of arc.

With the Mann machine, the film is placed on the comparator near a zero-degree orientation; i.e., with the oscilloscope edge toward the measurer. The satellite image is brought to a point near the center of the target screen. The stage of the Mann machine is rotated until the trail of the satellite is as nearly parallel with the horizontal cross-hair as is possible, and the stage is locked. The satellite image (or central break) is brought to the cross-hair intersection. The two plane coordinates, x and y, of the reference stars and the satellite are then measured. The stage of the Mann machine is then rotated 180° and the measurements are repeated. This is done to eliminate the magnitude error—a systematic but not a constant error of the observer.

For the computation of the 6 plate constants, the measurer used 6 stars, employing the least-squares method to compute the 6 constants from 12 equations. When there were large residuals, one or two reference stars were sometimes omitted. If large residuals still remained, he repeated the measurements, never using fewer than four comparison stars.

A measuring accuracy of 1 micron (which corresponds to 0.4 second of arc on the Baker-Nunn films) or better can be achieved with the Mann comparator.

Before the introduction of the completely automatic equipment the x and y coordinates were read by eye and written down by hand. These data as well as the catalog data on the reference stars were punched on tape by a Flexowriter and the position of the satellite was computed by a Burroughs E–101 computer using the Flexowriter tape as input. The computation with this machine took about 30 to 40 minutes.

As a preliminary step, the two machines were used to locate "unknown" stars from the Yale catalog by measuring their positions relative to nearby reference stars also selected from the Yale catalog. By this means, the nature and extent of several sources of error could be determined. First, of course, there were the errors inherent in the machines themselves. For example, the Mann engine was operated by means of a periodic screw and a secular screw; each of these mechanisms had to be evaluated.

Second, there was the human element. Each person using the machine would do so in his own particular way; he would handle the machine in an individual fashion and would be more or less accurate compared to other measurers. The personal error could in general be eliminated, however, by making direct and reverse measurements of

the unknown star and reference stars in the preliminary testing of the machines.

Third, there inevitably would be errors in the setting of the machine. Preliminary estimates indicated, for example, that when images of 40-micron diameter were measured with the Mann machine, there was, in the settings, a consistent and repeatable error of 1 micron on the average.

A further error could be introduced by the camera itself, although it seemed unlikely that the geometry of the Baker-Nunn system would cause any very considerable error of this sort. In any case, it had to be determined whether the image of the star on the film would be of such a magnitude as to introduce a significant variation in the measurements.

Finally, and most importantly, distortion of the film as placed in the machine might introduce a substantial error. That distortion would not be the same in every direction, and therefore positions reduced with linear plate constants might not be reliable. However, over small distances of 1 or 2 centimeters of film, it was expected that fluctuations in the plate-scale would be small, not exceeding 1 or 2 seconds of arc. The staff devised a simple method of evaluating this problem by measuring the same grouping of stars on several separate frames and then studying the residuals and positions from frame to frame.

By mid-1958, the photoreduction section had developed an efficient system of filing the films, had undertaken the searching of films with microscope viewer, and was planning the techniques for measuring the satellite images on the films. Again, this was a two-fold problem, one of developing appropriate methods, and the other, at the same time, of training personnel to use them.

Precision reduction of the Baker-Nunn films of artificial satellites began in June 1958, and by the end of September the positions of some 69 satellite images had been precisely determined. It was initially a very slow procedure; a trained operator could measure between four and six satellite images per day with either the Van Biesbroeck or the Mann measuring engine.

The initial phases of the work had been carried out by Pedro Kokaras, under the immediate supervision of Drs. Whipple, Hynek, and Henize. In October, however, Dr. Karoly Lassovszky, a refugee from Hungary, joined the staff as astronomer in charge of photoreduction. Mr. Kokaras then served as his administrative and technical assistant and supervised the work of the measurers.

During the last quarter of 1958, some preliminary evaluations of the two measuring engines were possible. In those 3 months, 94 images were measured on a modified Van Biesbroeck machine, with a mean estimated probable error of 7.4 seconds of arc in right ascension, and 5.5 seconds of arc in declination.

Meanwhile, the staff was working on the problem of measuring films with the Mann machine. The positions of nine images were reduced with a probable error in right ascension of 1.05 seconds of arc, and in declination of 0.54 second of arc. At the same time, a program was written for the reduction of measurements made by this machine so that computations that required 1 or 2 days by hand could now be performed on a Burroughs E–101 electronic computer in some 15 minutes. This was the first step toward automating as much of the procedure as possible.

As a further step to facilitate the work, a special project was undertaken to assign Yale catalog numbers to the BD and CD star charts.

Precision reduction of the films continued, so that in the first quarter of 1959, a total of 155 satellite images were measured and in the second quarter 109. Meanwhile, however, the Baker-Nunn stations were taking films at a considerably faster rate; during the same 6-month period, more than 4,000 films were received in Cambridge. Clearly, more rapid and efficient means of measuring the films remained to be found and put into practice.

COMPUTATIONS

Before Explorer I was launched early in 1958, the Observatory had developed two computer programs that were to be the basis for the determination of orbits and the preparation of predictions for the next year and a half (see Part 2 of this history [2]).

From a set of observations of a satellite the Herrick-Briggs-Slowey initial orbit determination program was used to derive the orbit without any previous knowledge of it. With a program of this type, the accuracy cannot be high since usually only three observations are used for the calculation of an orbit. However, an initial concept of the elements of the orbit can be obtained.

Two major improvements were soon made in the program. First, an empirical correction for air drag used an expression for the nodal period as input and computed the corrections to the observations necessary to give the osculating orbit at the time of the first observation. The second provided an alternate method of interpolation when the usual method failed. In this mode of operation, the program must find any and all elliptical solutions in a given range that fitted the observations.

By mid-1958 the program was fully debugged, tested, and completely operational in all of its essential parts. Proof of the usefulness and accuracy of the program was demonstrated by its application to the tracking of 1958 Delta. The program was used not only to obtain an initial orbit but also to follow the changes in the orbital elements.

[2] See footnote 1 on page 315.

Thereafter a number of simple, but relatively important refinements were made in the program as the computations group of the Observatory became more sophisticated in their approach.

The second program was the subsatellite procedure, developed by Dr. Luigi Jacchia, which provided a quick analysis of incoming observations. From each observation, a subsatellite point was computed from a given set of orbital elements derived from the initial determination program. From the subsatellite points, the position and time of the crossing of the ascending node were computed, as well as the nearest perigee crossing. A plot of these quantities was sufficient to tell whether the observation was good or bad.

The subsatellite program could be used to predict all the modifications of the orbit. One had only to follow the position of the satellite; therefore, air drag could be determined as a byproduct of the program. It was an empirical approach, but the modifications of the orbit were observed; from these one could deduce theoretically the changes of the orbit. Again, during the months that followed, the staff was to make various improvements to this program.

Using input from the subsatellite program, the ephemeris 0 gave the time of crossing of a satellite at various parallels—10°, 20°, 30°, etc.—with height, correction for time, angle of trajectory, and so forth, so that an observer with a minimum amount of calculation could work out fairly accurately the appearance of a satellite transit from his particular position. This program was started shortly after Sputnik I was launched, and became the basic prediction procedure for Moonwatch teams and for people interested in making their own observations of the satellite.

For the Baker-Nunn camera stations, however, a somewhat more complex ephemeris was required. By early 1958, the basic programing of the detailed station ephemeris was completed and debugging was in process. Not until a year later, however, was the program fully operational. By February of 1959, it had proved itself to be completely satisfactory and thereafter only minor refinements were made.

Meanwhile, during the latter part of 1957 and continuing for several years, Dr. Cunningham's major project was to develop a very precise method of deriving, from the details of the equations of motion, the position of a satellite as a function of time. This approach meant starting with an initial position of the satellite in terms of its velocity and time. Then, by numerical integration, which simply means step-by-step calculations using intervals of perhaps one minute or less in time, the position of the satellite is computed. This numerical integration program represents a difficult procedure if one wishes to carry out the calculations for, let us say, 10 days in

which time the satellite may perform as many as 150 revolutions around the earth. During this period, any errors made by not computing enough significant figures tend to accumulate.

Cunningham's effort was aimed at constructing a program that could be used as a standard reference for computing accurate, definitive orbits after all the observations were in, and for checking more approximate theories. His work was not intended to provide a practical approach to computing orbits on a day-to-day basis, for his program required at least one minute to compute a single orbit of perhaps an hour and a half.

By mid-1958, the program was being debugged and checked out. At the same time, it was being modified so that elements of it could be included in the differential correction program of Dr. Lautman.

The latter program had been completed by late 1958, thus providing an extremely accurate method of correcting orbits of satellites, with or without drag. Again, the large amount of computer time necessary for its operation precluded its use for day-by-day corrections and ephemerides. The Observatory expected, however, that its accuracy and general applicability would result in its use as a powerful tool for analysis, especially when geodetic satellites were available.

Both of these programs required that the magnitude of satellite drag, the size and shape of the satellite, and other physical parameters be known and included in the calculations. In contrast, a differential orbit improvement program developed by Dr. George Veis included virtually everything as unknown and approached the problem purely as one of defining the orbit without having recourse to theory. The theory came afterward once the motion of the satellite had been determined.

The Russians had developed such a program, which seemed the most practical way to compute orbits for generating predictions. Meanwhile, Veis had included in his doctoral dissertation at Ohio State a chapter on satellite-orbit computing that contained all the features of the Russian program. His method was entirely satisfactory from every point of view. He had worked it out independently and had not the slightest notion of what was being done elsewhere. When Dr. Whipple learned of the features of Dr. Veis' program, he asked that it be set up as quickly as possible for use at the Observatory.

Dr. Veis' program had originally been developed for geodetic purposes, that is, he planned to use it to determine precisely the positions of stations from which observations of satellites were made. The problem now was to invert that program in such a way that, the positions of the Baker-Nunn stations being relatively well known, the time and position of satellites could be determined from observations made from those stations.

In the summer of 1958, Dr. Veis, assisted by Charles Moore, a student at M.I.T., modified the program so as to omit its geodetic aspects. By the end of the year, they had a working program, although it still needed a good deal of effort to smooth out difficulties. In the spring of 1959, Dr. Veis presented a paper on this technique, at the N.A.S.A. conference on Orbit and Space Trajectory Determination in Washington; the program itself went into routine operation at about the same time.

This differential orbit improvement program, with the modifications that have been made since its inception, has proved to be the workhorse of the computing effort of the Observatory. In fact, it has so far exceeded its original purpose that it continues in the mid-1960's to be the best program for correcting orbits and has been used for the highly precise geodetic work of Imre Izsak and others, as well as for further refinement of measurements of upper atmospheric densities and temperatures.

Various other programs, many of them highly specialized, were also undertaken by the computations group of the Observatory in this period. Two merit special attention, since they were to have important bearing on the development of the satellite-tracking project after it came under the auspices of the National Aeronautics and Space Administration.

Mr. Slowey began a study of observing techniques and orbit determination methods relating to long-arc satellite transits. A primary purpose of long-arc observations would be to make simultaneous sightings of a satellite from two or more Baker-Nunn camera stations; the resultant data could be used to determine more exactly the geodetic positions of the stations themselves.

Dr. Veis initiated a long-range program of establishing a star catalog in punchcard format. This project would in time result in the preparation of the famous SAO catalog giving the positions and other data on more than a quarter of a million stars.

While these and other programs were being developed, the computations group carried on its day-to-day activities with increasing efficiency and success. In the first quarter of 1958 they processed approximately 2,500 satellite observations, including some from Minitrack. This number steadily grew during the months that followed, so that from April to June of 1959, more than 12,000 observations were processed. The group achieved a similarly spectacular increase in the number of predictions of satellite transits sent to the 12 Baker-Nunn stations. From the meager beginnings late in 1957, the figure rose to 1,700 for the last 3 months of 1958, and to 6,700 for April through June of 1959.

RESEARCH AND ANALYSIS

Once satellites had been launched and tracked, and observations of them reduced to precise statements of time and position, there remained the most important job—the use of these data for scientific purposes. Satellite orbits are sensitive to a number of influences—the earth's gravitation, atmospheric density (which changes with both electromagnetic and corpuscular solar radiation), and the pull of the sun and the moon. By means of powerful mathematical tools, including computer programs especially developed for the purpose, scientists are able to separate these influences from one another and to measure them individually. From this study have come some of the most exciting and significant discoveries of the space age.

Late in 1957 Dr. Allen Hynek, associate director of the Observatory, outlined such a program of satellite research and analysis. He proposed to reduce and analyze the data from visual and photographic observations of earth satellites: "Data are now being received at the Smithsonian Astrophysical Observatory from stations and observatories on a worldwide basis. . . . The project would extend the present work to future satellites, conduct basic research on the reduced data with the objectives of determining values of upper atmosphere density, geodetic parameters, and the value of gravity in geopotential. Preliminary results will be published in special project reports for rapid dissemination among the scientific community and final results will be published in standard scientific journals."

Already the Observatory had undertaken such a program, and had issued six Special Reports on Sputniks I and II, including a preliminary estimate on upper atmospheric density derived from observations of Satellites 1957 Alpha and Beta. The call now was for a greatly expanded project that could adequately handle the many data and derive maximum scientific results from them.

By mid-1958, when the project was well under way, Dr. Whipple wrote to Mr. Odishaw: "I want to underscore the real need for more scientists and money for rapid reduction and interpretation of the data obtained. In my opinion this problem will reach crucial proportions not only in the rocket and satellite fields but also in other IGY areas where you are faced with the accumulation of a considerable amount of raw data in very complex form." More scientists and more monies were forthcoming, and the Observatory developed a major program of research and analysis.

The plan of the IGY was to launch satellites that could contribute to the gathering of information about the earth during those 18

months. The period from July 1957 through December 1958 had been selected to coincide with maximum activity in the sun. Since solar phenomena involving ultraviolet and corpuscular radiation cannot be observed on the ground because the atmosphere cuts off most or all of their effects, the satellites were to carry instrumentation that would measure these and other astrophysical events and telemeter the data to ground stations.

The initial purpose of the Observatory's program for the optical tracking of satellites was primarily surveillance—that is, to keep the object in view as it went around the earth, particularly if its radio transmitter failed for one reason or another. In fact, the transmitters in several of the first satellites did fail, so that the optical system was often the only means of tracking.

The Smithsonian Astrophysical Observatory planned also and more importantly to make secondary use of these satellites. It was to track them as passive objects and analyze the resultant data to derive new knowledge about the earth and its atmosphere.

The satellites could, of course, be tracked by other means—radio, radar, and doppler measurements in particular. At the time, however, none of these was nearly so accurate as the optical techniques developed by the Observatory. Optical tracking was based on astronomical methods that had been refined over a long period of time and were well understood by scientists. The other methods were relatively new, and until actually employed in the tracking of a satellite were not wholly predictable. These techniques were quickly refined following the launching of Sputnik I.

The first American discoveries from satellites were made almost entirely with Moonwatch observations of Satellites 1957 Alpha and Beta. For Satellite 1958 Alpha the observations were primarily Baker-Nunn. And for Vanguard I, the observations were mainly Minitrack, because the satellite was too faint except for occasional observations by the Baker-Nunn cameras. All of these observations were used for research purposes and it was Vanguard I from which the most important early determinations concerning the structure and variation of the upper atmosphere were derived. These facts serve to emphasize once again the close and necessary cooperation that existed among the projects of the IGY and that continues today among the various programs of the U.S. space effort.

The first satellite research of the Observatory concerned the upper atmosphere. The atmosphere had already been explored by balloons and probed by rockets to a height of about 200 kms., and approximate profiles of temperature, density, and composition drawn for that region. What scientists now wished to do was to refine that picture and to extend it to the boundary of the interplanetary medium. They had realized from the first, of course, that passive satellites could be

used for the determination of atmospheric density and temperature. They would thus be able to obtain corrections to the profiles that had been more or less guesswork before the first satellites were launched. What they had not realized was that there were such large variations of the atmospheric density related to phenomena outside the earth and that the satellites, simply through the irregularities of their motions, could monitor those variations.

Dr. Jacchia has described the motion of a satellite in orbit:

> In a first approximation, then, we can say that the satellite describes an elliptical orbit, but the plane of this ellipse slowly rotates, and the major axis of the ellipse rotates in this plane. Moreover, we shall find small periodic deviations from the elliptic motion in the course of one revolution. The motions of the orbital plane and of the major axis are progressive and slow when compared to the orbital motion; they are called secular perturbations, a term taken from the theory of planetary motions, in which the period of such perturbations amounts to many centuries. All the other gravitational perturbations are much smaller and of an oscillatory character, and are called periodic perturbations.

Atmospheric density causes a "drag" on the motion of the satellites. Continuing with Dr. Jacchia's description:

> This atmospheric drag has seemingly paradoxical effects. While a gun projectile is decelerated by drag in the course of its trajectory, the same drag accelerates a satellite in its orbit. The reason for this paradox is that drag causes the satellite to lose energy and to fall to smaller orbits in which the period of revolution is shorter. Although the kinetic energy of the satellite increases, the total energy involved in the course of one revolution decreases. . . .
>
> Much information about the upper atmosphere can therefore be derived by analyzing the motion of satellites. The rate at which the satellite's period decreases with time—the so-called orbital acceleration—yields a value for the atmospheric density at perigee height. True, to have an accurate determination of density we must first know how the density varies with atmospheric height (the local "scale height"). Then we must have an exact knowledge of the drag mechanism, and we must make sure that no drag other than atmospheric drag operates on the satellites. And finally we must know the exact physical characteristics of the satellite (if the satellite is a sphere, the problem is relatively simple; not quite so simple if it is a cylinder or an irregular body).

At a meeting at the Observatory in 1957, scientists adopted a model atmosphere based on the latest results from rocket and balloon explorations. Virtually all research to that date consistently underestimated atmospheric densities above 100 km. Before any satellites were launched, Dr. Theodore E. Sterne of the Observatory's staff worked out a theory of orbital variations due to drag. However, he and other scientists prayerfully hoped that the drag would be so small that in fact it could be taken into account by empirical corrections in orbit computations; that is, they expected that once the satellite was up, they could then best determine corrections for atmospheric drag to be included in the computations.

The first efforts to derive the orbit of Sputnik I, launched October 4, 1957, from early observations by Moonwatch teams convinced sci-

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entists that at the altitude of its perigee—approximately 220 kms. above the earth—there was a good deal more atmospheric density than had been anticipated. On November 6, the Observatory and the U.S. Naval Research Laboratory jointly announced preliminary results from the tracking of the Soviet satellite. Whereas pre-Sputnik estimates had indicated a density of 10^{-13} grams per cubic cm., analysis of the orbit of Sputnik I now suggested a density of perhaps five times that amount. These calculations had been made by Dr. Sterne, assisted by Dr. J. S. Rinehart and Dr. G. F. Schilling.

They had, then, the rather paradoxical situation that one of the reasons for sending up a satellite was to determine atmospheric density, but that a fairly good estimate of the density was needed in order to compute orbits and make predictions of satellite transits.

A milestone in research and analysis of satellite data was reached in May of 1958 at a meeting of the American Geophysical Union at the National Academy of Sciences, Washington, D.C. There, some of the results on Explorers I and III were summarized. Dr. Van Allen presented his conclusions concerning the existence of a radiation belt around the earth. Other scientists made preliminary estimates of the concentration of meteors at the altitudes at which the satellites were orbiting. And Drs. Schilling and Sterne offered a summary of tentative conclusions concerning the density of the upper atmosphere as derived from satellite observations; table 3, which appears in the Observatory's Special Report No. 12, dated April 30, details their results.

The authors noted that these estimates were made from observations at different geographic latitudes and that the data were too few to provide an accurate mean value. They further cautioned that the estimates were not strictly comparable because no allowances had been made for seasonal, diurnal, and other sporadic variations of air density. These were now to become a major concern in the study of atmospheric phenomena.

Meanwhile, the Observatory had incorporated into its program for the computation of orbits the changes of period caused by air drag. They found, however, that they were still faced with rather serious errors in predictions, although not nearly so bad as they had been earlier. The problem was complicated by the fact that Sputnik II and Explorer I were not spherical; therefore, as their orientation changed in space, the amount of surface against which atmospheric density could act to decrease the altitude and increase the speed of the satellite changed.

Nevertheless, the variations in satellite drag from day to day did not seem accountable by considerations of the presentation area. When the spherical satellite Vanguard I showed the same type of oscillations that had appeared in the orbits of Sputnik II and Explorer I,

TABLE 3.—*Atmospheric Densities Derived by Various Investigators*

Height (kilometers)	Density (gm/cm³)	Satellite	Author
368	1.5 10^{-14}	1958 Alpha	Sterne.
368	1.4 10^{-14}	1958 Alpha	Sterne.
275	8.5 10^{-14}(?)	1957 α2	Harris and Jastrow.
241	2.5 10^{-13}	1957 α2	Royal Aircraft.
233	2.2 10^{-13}	1957 β1	Sterne and Schilling.
232	1.5 10^{-13}(?)	1957 α2	Harris and Jastrow.
220	5.7 10^{-13}	1957 α1	Sterne and Schilling.
220	4.5 10^{-13}	1957 α2	Sterne and Schilling.
220	4.0 10^{-13}	1957 α2	Sterne.
215	4.7 10^{-13}	1957 α2	Priester *et al.*
212	4.8 10^{-13}	1957 β1	Sterne and Schilling.
212	4.4 10^{-13}	1957 β1	Sterne and Schilling.

their origin had to be sought in the atmosphere itself rather than in the shape of the satellite.

Dr. Jacchia discovered that the oscillations had a period of approximately 27 days, equal to that of the sun's rotation, and immediately surmised that the cause of the variations of density in the atmosphere revealed by these variations of drag might be solar radiation.

He outlined this possibility in a paper entitled "The Erratic Orbital Acceleration of 1957 Beta" in the April 1958 issue of *Sky and Telescope*. When Dr. Wolfgang Priester of Germany studied the text, he noted that the curve of the drag of Sputnik II resembled the variations of the 20-cm. radio flux from the sun. The resemblance could not be seen clearly because unfortunately there were just two minima and one maximum on the curve, and the satellite's perigee went from night into day and back into night exactly at the time when the drag was rising and then declining. The curves did, however, appear to be similar.

By the time Priester had made this analysis, Jacchia had many more data at hand, including several months of observations of Vanguard I for which he had not published any detailed accelerations. Since he did not have access to the 20-cm. flux, which is measured in East Berlin, he made use of the 10-cm. flux which behaves very much like the other, and which is measured in Canada. He plotted the 10-cm. flux against the drag of Vanguard I. The two curves were almost identical: every single minimum and maximum in one was reflected in the other. There could no longer be any doubt of a relationship between something that was happening in the sun and something that was happening in the atmosphere to affect the motion of the satellite.

It must be emphasized that there is no direct causal relationship between the 10-cm. flux and the variations of the density, since the atmosphere is completely transparent to that radiation and therefore

cannot be heated by it. There simply must be another kind of radiation in the sun that varies in more or less the same way as does the radio flux and that influences the orbit of the satellite.

It was reasonable to assume that extreme ultraviolet radiation, including soft X-rays, emitted from sunspots varies in a manner similar to that of the 10-cm. radiation; that is, the same primary cause underlies the two phenomena and therefore they are in unison. If this is true, then the 10-cm. flux serves as a fairly accurate indicator of variations of the emission of the extreme ultraviolet. The latter cannot, of course, be observed from earth because it is completely shielded by the atmosphere. Its existence, however, had earlier been confirmed and measured by rockets lofted before the IGY. Since sunspots have a tendency to concentrate in a few long-lasting active areas, the radio flux and the extreme ultraviolet flux will show a maximum every 27 days when the rotation of the sun brings them near the center of the visible disk. And since the number of sunspots greatly varies with the 11-year solar cycle, there is a corresponding variation in the two fluxes, which is reflected in the heating of the atmosphere. Actually, this variation with the 11-year cycle is by far the largest observed in the atmosphere.

This, then, was the first major discovery concerning variations of upper atmospheric density made from the tracking of satellites. The importance of this finding has frequently been compared to that of the Van Allen radiation belt.

Shortly after the discovery of the 27-day variations, another kind was found from observations of the rocket of Sputnik III (1958 δ1). Jacchia noted that one two occasions during the lifetime of the object the drag increased much more suddenly than it did during the 27-day fluctuation. Each of these increases occurred within a matter of two days, one during which density rose, and the other when it fell. He then searched for any unusual happening on those days. They proved to be the dates of the only two large magnetic storms during the lifetime of the satellite. The maximum of each storm coincided with the maximum of disturbance in the drag to within a fraction of a day. Once he computed the acceleration curves and compared them with the magnetic indices, he found that they were almost identical.

Such magnetic storms are caused by solar flares. In both cases, in July and in September, the magnetic storms started approximately 24 hours after the appearance of a +3 flare on the sun.

The agent that caused the storm was corpuscular radiation. Its role in heating the atmosphere was completely unknown before the space age. Violent flares on the sun emit charged particles. When they are in the vicinity of our planet, they interact with its magnetic field and cause perturbations of the magnetic needle. The same particles indirectly also cause the temperature of the atmosphere to in-

crease and therefore its density at a given altitude. It must be added that scientists do not yet understand precisely how this heating occurs.

The next discovery by Dr. Jacchia was that the atmosphere at a given height is denser in the illuminated—that is, the bright—hemisphere than it is in the night hemisphere. In other words, the atmosphere bulges out toward the sun. This diurnal bulge is another phenomenon caused primarily by the extreme ultraviolet radiation from the sun.

At a height of 150 km., surfaces of equal density in the atmosphere are nearly concentric with the earth. At higher altitudes, however, a slight bulging out occurs around the point that is at the same latitude as the subsolar point but shifted 2 hours in longitude. This bulging out reaches a maximum in the region between 600 and 1,000 km.; the bulge then decreases in the helium and hydrogen regions of the atmosphere. The temperature goes up much more sharply in the bulge. At the height of Vanguard I, for example, the density of the atmosphere in 1958–59 varied by nearly one order of magnitude across the bulge; the density increased by nearly one order of magnitude going through its center, and then decreased.

A fourth effect of solar radiation is the semiannual variation. In 1960 Professor H. K. Paetzold found from Dr. Jacchia's observations of Vanguard I and Satellite 1958 Alpha that there are indications of a small semiannual oscillation in the drag. His discovery was then substantiated by Priester and Jacchia. The maxima and minima of this oscillation agree with the maxima and minima of the semiannual oscillation in the geomagnetic indices and with the maxima and minima of aurorae and magnetic disturbances.

Again, the mechanism of this variation is not understood. The changing dip of the magnetic axis of the earth with respect to the "solar wind" has been invoked to explain the effect, but this explanation seems to meet with increasing difficulties.

From all of these observations and deductions, a new model of atmospheric heating resulted. The troposphere extends to between 8 and 12 km. from the ground. The ground is heated by visible radiation; then the heat is transferred from the ground to the atmosphere by conduction and convection. Above the troposphere is the ozonosphere, the layer of atmosphere that contains a quantity of ozone which absorbs the near ultraviolet; most of this region is between 25 and 40 km. above the earth. The layer above is heated from the ozonosphere in the same way that the troposphere is heated by the ground. These facts had already been available, however, to estimate the nature and extent of heating in the upper atmosphere above 100 km.

In 1957 the most popular hypothesis on the heating of the upper atmosphere was Chapman's idea that the heating occurred by conduction from a hot interplanetary space that was part of the solar corona. The belief was that the earth moved in a thin medium with a temperature of something of the order of a quarter of a million to possibly a half-million degrees and that this heat percolated by conduction into the atmosphere. This conception proved to be completely wrong, for in fact the temperature of the upper atmosphere above a given point of the earth and at a given time is just about constant from 300 km. upward, at a relatively cool level, about 1000° to 2000° Kelvin.

Both the extreme ultraviolet radiation and the heating energy from the corpuscular flux from the sun seem to be absorbed at comparable heights of the order of between 100 and 200 km. above the earth. This layer has the same role for the upper atmosphere as the ground has for the troposphere, except that instead of convection there is only conduction. The lower regions heat the upper regions. The extreme ultraviolet and the heating energy from the corpuscular radiation directly heat the atmosphere, and then heat the layers above by conduction.

The temperature of the atmosphere does not increase constantly as one goes upward. Actually, it increases in a tremendous leap in the region between 100 and 200 km., going from 200° Kelvin at 90 km. to a possible 2000° Kelvin at maximum sun activity in a matter of 100 to 200 km. Then it remains stationary in the higher regions of the atmosphere. In other words, it is almost an inverted picture from what had been anticipated before the IGY.

In summary, extreme ultraviolet radiation from the sun heats the atmosphere unequally in the dark and bright hemispheres and thus causes the diurnal effect, and it varies from day to day and therefore creates the erratic "27-day" effect, as well as the 11-year variations. Corpuscular radiation from the sun indirectly heats the atmosphere during magnetic storms and may or may not be related to the mysterious semiannual effect. These, then, were some of the major scientific results derived from optical observations of satellites during the IGY.

Scientists at the Observatory also undertook other research programs as part of the IGY. From observations of Satellites 1957 $\beta 1$ and 1957 $\beta 2$, Dr. Jacchia derived new values for the second- and fourth-order coefficients of the earth's gravitational potential. Dr. Kozai made a theoretical study of the motion of a satellite by taking into account the second-, third- and fourth-order terms of the earth's potential; his results provided more accurate expressions for the secular motions of the perigee and the node. He also developed a theory of secular perturbations on satellite motions caused by the sun and the moon. Other scientists began developing further means

for using satellite observations in geodetic studies. These and other programs of research and analysis were to reach fruition after the IGY when the Satellite-Tracking Program of the Observatory came under the sponsorship of the National Aeronautics and Space Administration.

ACHIEVEMENTS DURING THE IGY AND IGC

When the Satellite-Tracking Program came under the National Aeronautics and Space Administration on July 1, 1959, the Observatory's direct participation in the International Geophysical Year and the International Geophysical Cooporation ended.

The changes, the progress, the achievements of the program during those years had been momentous.

The Observatory staff—most of whom were involved in the satellite program in one capacity or another—grew from 3 when the Observatory moved to Cambridge in 1955 to a cosmopolitan group of more than 175 people.

In 3 years, the Observatory built and manned a worldwide network of 12 stations, each equipped with a specially designed and constructed Baker-Nunn camera and Norrman time standard. The camera was so sensitive and so accurate that it photographed the Vanguard 6-inch sphere at a distance of some 2,400 miles; the clock could display time to one-thousandth of a second. By mid-1959 these 12 stations had made more than 4,000 photographic observations of U.S. and U.S.S.R. satellites launched during the IGY and IGC.

A communications network linking the stations with headquarters in Cambridge handled each month 400,000 words of information on predictions and observations of satellite transits.

More than 8,000 volunteers joined the Moonwatch program of visual observations of satellites. More than 200 teams were organized, not only in the United States but also throughout the world. Together, they made nearly 10,000 observations and were of unique value in locating several "lost" satellites and in observing the demise of Sputnik II.

Techniques were developed for the precise reduction of the films from the Baker-Nunn cameras, and by June 1959 the times and positions recorded on the photographs were being routinely determined.

The computations group successfully evolved a series of programs, among them the DOI, for the generation of predictions to the camera stations and the Moonwatch teams and for the derivation of precise orbits. They also created a number of other significant programs for research and analysis.

Scientists used the observational data to define several influences on the motion of satellites and thereby made new estimates of atmospheric

density and discovered the role of solar electromagnetic and corpuscular radiation in heating the atmosphere. Other research using satellite data was initiated in studies of geodesy.

Members of the staff presented some 20 papers to scientific meetings, and published 30 others in leading scientific journals. The Observatory issued 27 special reports on research in space science, ranging in subject from observational data to plans for a flashing satellite for geodetic studies. In the years to follow, literally scores of other papers and reports based on IGY activities were to appear.

The imaginative vision of 1955 had become a splendid reality.

How Mountains Are Formed[1]

By R. A. Lyttleton

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[With 2 plates]

The existence of mountains has remained for generations one of the most perplexing problems of geology and geophysics despite the enormous amount of evidence apparently available. True, we have been told since childhood that mountains are due to shrinkage of the Earth as it cools causing corrugations as on a withered apple. But a purely verbal explanation of this kind represents only the first glimmerings of a theory. Before any theory can be regarded as satisfactory, it has to show that all the proposed processes would occur to correct numerical amount. If experiments are not possible, this can be done only by working out the mathematical consequences of physical laws. A verbal theory can keep the moon swinging around the Earth with a piece of cotton, but as soon as numbers are put into the scheme it founders. This has happened to various theories of the origin of mountains.

The geologist can explore the surface of the Earth in all its detail. As yet, the prospector can bore down only a small distance, but he can examine present surface rocks and features that must formerly have been buried much deeper. The geologist can see sedimentary layers, which were originally deposited horizontally, so compressed from the sides as to be folded and contorted here, and sheared and thrusted layer-over-layer there (pl. 1, upper fig.), and also uplifted and turned through large angles. He can examine lands that at one time formed seabeds, and he can examine intrusive rocks and lavas poured out in seemingly gigantic amounts from volcanoes. He can tunnel through mountains and examine them in all their forms. This has been done on an immense scale but has produced few clues as to the ultimate cause of mountains except to show that worldwide compressive forces have been at work. The origin of the forces has remained a mystery.

[1] Reprinted by permission from *Discovery* (London), vol. 25, No. 2, February 1964.

One of the reasons for this is that the accessible material is far less than one-thousandth part of the whole mass of the Earth. In this minute proportion, the geologist nevertheless finds signs of almost every kind of disturbance that could be conceived, with the result that almost any conjecture about the Earth's history can find some apparent evidence for its support. This renders the task of the theorist both difficult and thankless. However, one general conclusion has emerged from this work, and that is that the outer crust of the Earth has undergone considerable horizontal shortening, as if to fit down on to a decreasing and shrinking interior. The problem is to find the cause of this contraction.

CONVECTION CELLS

One obvious suggestion is that at one time the Earth rotated much faster than now. This would have caused it to have bulged out far more at the equator than at present. As the shape became less spheroidal, this would lead to crumpling at the surface, presumably mainly along meridional lines. There is certainly some evidence of a greater rotation rate in the past, but this theory would place the greatest changes in surface area far back in the Earth's history, whereas mountain building is still going on now, even though changes of surface area due to changes of shape are negligible.

An entirely different theory maintains that the mountains are produced by the drag of circulating convection currents actually flowing in the Earth's solid mantle (*see* fig. 1). It is considered that such currents would have a pattern, dividing off into a certain number of convection cells just filling the volume of the mantle. From time to time, as a result of the increase in size of the liquid core of the Earth, the number of cells would have to increase by one. The drag on the surface layers, if effective at all, would be producing mountains all

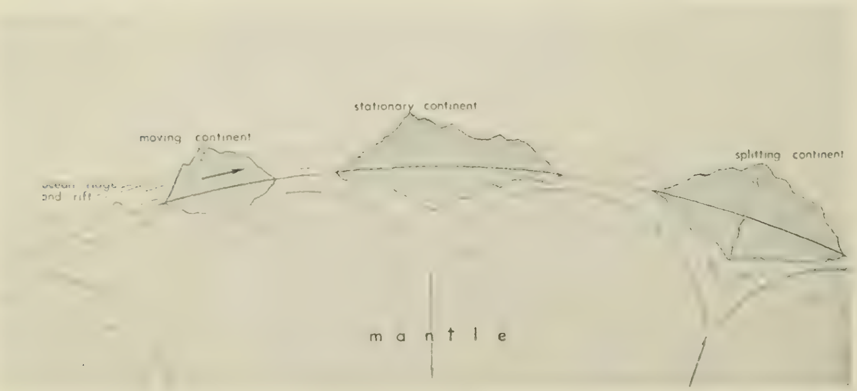

FIGURE 1.—The diagram shows how circulating convection currents in the solid mantle deep within the Earth are supposed to give rise to surface features. These convection-cells are also supposed to account for Earth's drifting continents.

These strata of sedimentary rock would be horizontal when first deposited. Changes in the Earth's crust as it shrinks cause thrusting, folding, and compression of the rock layers. These distortions of rock are found on every scale from relatively small changes like this to whole mountain ranges such as the French Alps.

The Earth probably developed from a cool, low density cloud of gas and dust such as the one shown here in the "horsehead nebula" in Orion. Subsequent heating and formation of a liquid core would have caused the Earth to contract.

Deep gash of the Grand Canyon in Arizona illustrates vividly the powerful forces of uplift and erosion that produce the Earth's surface features.

the time (and as an additional flourish would make the continents drift), and the readjustment when the number of cells increased is associated in the theory with a period of intense mountain building.

Ingenious as this descriptive theory is, it is hard to see why horizontal currents near the surface should produce such enormous uplifts, and it is even more difficult to see why such currents should occur in solid matter of considerable strength. It is difficult to prove one way or the other whether a sufficient force will cause "solid" material to flow if applied long enough, but there is recent evidence from the motions of artificial satellites that the Earth may possess enough strength to maintain a slightly more spheroidal form than its present rotation warrants (presumably a relic of a time of faster rotation). This could tell heavily against the notion of convection currents. The mechanism would also require regions of unequal heating to produce currents, or some other departure from symmetry. Moreover, the theory requires a growing core, and for this the theory speculates still further and assumes that free iron is present deep within the solid mantle. Because this iron would be heavier than the surroundings, it would sink gradually to build up a metallic core. The Earth does in fact contain a heavy core, almost entirely liquid, with radius now some 55 percent of the whole Earth-radius, but the presence of the requisite chunks of iron is highly dubious. A body containing nearly 40 percent of heavy metals would be a cosmic object of the utmost curiosity.

THE EARTH'S ORIGIN

Several epochs of mountain building have now been traced right back in time by the geologists. There have been at least three major periods well authenticated in post-Cambrian times (that is, within the last 500 million years). Numerous others occurred over a range of some thousands of millions of years, with their greatest intensity at intervals of the order of a hundred million years. Thus any inquiry as to the origin of mountains must face the question of the original state of the Earth. It seems to be here that a new approach may bring order where for so long there has seemed to be only difficulty and contradiction.

For almost a century it has been widely believed that the Earth began its existence as an entirely molten body, so that its development seemed to be explicable simply by the processes of cooling of such a body. Indeed, the thermal-contraction hypothesis, whereby the mountains are supposed to result from this cooling as it extends downward, has long been regarded as the obvious cause. The surface would cool first and become solid to a certain depth, and then, when a lower layer cooled and contracted, the already solid outer crust would find itself too large to fit continuously over the cooled adjacent interior. It

would therefore buckle and thrust over itself sideways, piling up material against gravity.

Attractive and inevitable as this mechanism seemed, detailed calculations showed that it was likely to give far less contraction than would satisfy the geologists. Measured in terms of circumferential contraction of the entire globe, it might lead in the whole age of the Earth to a reduction of a hundred kilometers or so. The geologists need at least a thousand kilometers—some would prefer even two or three times this amount—to allow adequately for all the earlier periods of mountain building.

But even more serious doubt has been thrown on this hypothesis by the gradually emerging conclusion that initially the Earth may have been sufficiently cool to have been solid throughout. When proposals for the origin of the planets were under review a few decades ago, the only possible source for material seemed to lie in the stars, and here all the material was known to be at very high temperatures. Could released stellar material settle down into a compact planetary mass straightway? It now seems much more likely that material removed from a star by some catastrophic occurrence would expand almost indefinitely, thereby cooling, and instead of giving rise to a planet would produce a gigantic low-density cloud of gas and dust. The heavens, it is now established, are replete with such clouds, which occupy some 10 percent of all galactic space (pl. 1, lower fig.). It thus becomes necessary to think in terms of planets developing initially from cool material.

There are a number of mechanisms by which the sun could have acquired sufficient dust and gas to form all the planets. For example, a companion star to the sun may have exploded as a supernova to provide the material; alternatively, the sun may have nosed sufficiently slowly through one of these clouds to form a dust-and-gas cloud circulating round itself. (The clouds themselves would possess slow circulation in the first place.) Once captured, a cloud of gas and dust would settle down into a thin disklike form moving round the sun, somewhat resembling a giant Saturn's ring but on an immensely larger scale and much further out in proportion. Within this disk the planets would have grown by a process of gradual accretion. But for present purposes it is not necessary to go into the details of all this: it is sufficient if we postulate an initially cool and entirely solid Earth, and ask how such a planet would develop.

SIZE OF AN ALL-SOLID EARTH

If then we imagine all the material of the Earth initially gathered into a single all-solid body, almost the first question that springs to mind is to ask how big such a planet would be. To answer this with

any worthwhile degree of accuracy would be an almost impossible task were it not for the occurrence of earthquakes. For study of their wave effects has enabled a great deal to be learned about the pressures, densities, and elastic properties of the material existing at all depths within the present Earth. The pressures inside the Earth are of the order of millions of atmospheres, and far above the strengths of solid materials in all but the extreme outer layers. This great pressure renders the problem tractable, for the internal material must be so distributed that it is supported against gravity entirely by pressure. The times of travel of earthquake waves enable the physical properties of the material, in particular its compressibility, to be found at these enormous pressures. This is obviously essential information if we are to calculate the initial size of the Earth.

If the Earth grew by accretion of cosmic dust, there would be no reason to suppose any great difference of composition from one part to another, and it would be easy to calculate the uncompressed volume that a mass equal to that of the Earth would occupy if composed of dust. However, the compression squeezes the matter to higher density, the more so the deeper it is inside the Earth, and it is this that makes the calculation awkward. It is necessary to have precise knowledge of how the density varies with pressure.

Geophysicists have long since determined the incompressibility at almost all parts of the Earth by their studies of earthquake travel-times. The results show that the incompressibility is almost exactly a linear function of the pressure (*see* fig 2). The same type of law had also been arrived at quite independently more than a decade ago from purely physical considerations. It therefore seems probable that such a law holds with an accuracy greater than that of the present geophysical data from which it can also be inferred.

It is found that a straight-line law holds not only throughout the solid mantle and the solid outer shell of the Earth (which is just over 400 kilometers deep), but also in the liquid core. The constant of incompressibility associated with zero pressure is different in each zone, but the slope of the straight-line law is the same. Our first requirement is to consider an all-solid Earth. Its radius is readily calculated by means of the linear law (and the use of a computer) and comes out to about 350 kilometers greater than the present Earth-radius of 6,371 kilometers. This means an initial circumference more than 2,000 kilometers greater than the present value, and a surface-area about 60 million square kilometers greater! This is the area that would have been tucked away by folding and thrusting to change the Earth to its present size. These are exactly the kind of changes the geologists need to account for all the epochs of mountain building (*see* fig. 3).

The pressure at the bottom of the mantle, 2,900 kilometers below the surface, is about 1.37 million atmospheres, whereas at the center of an entirely solid Earth it would be only just over 20 percent greater. Thus no more than a modest extrapolation of the law between pressure and density is required.

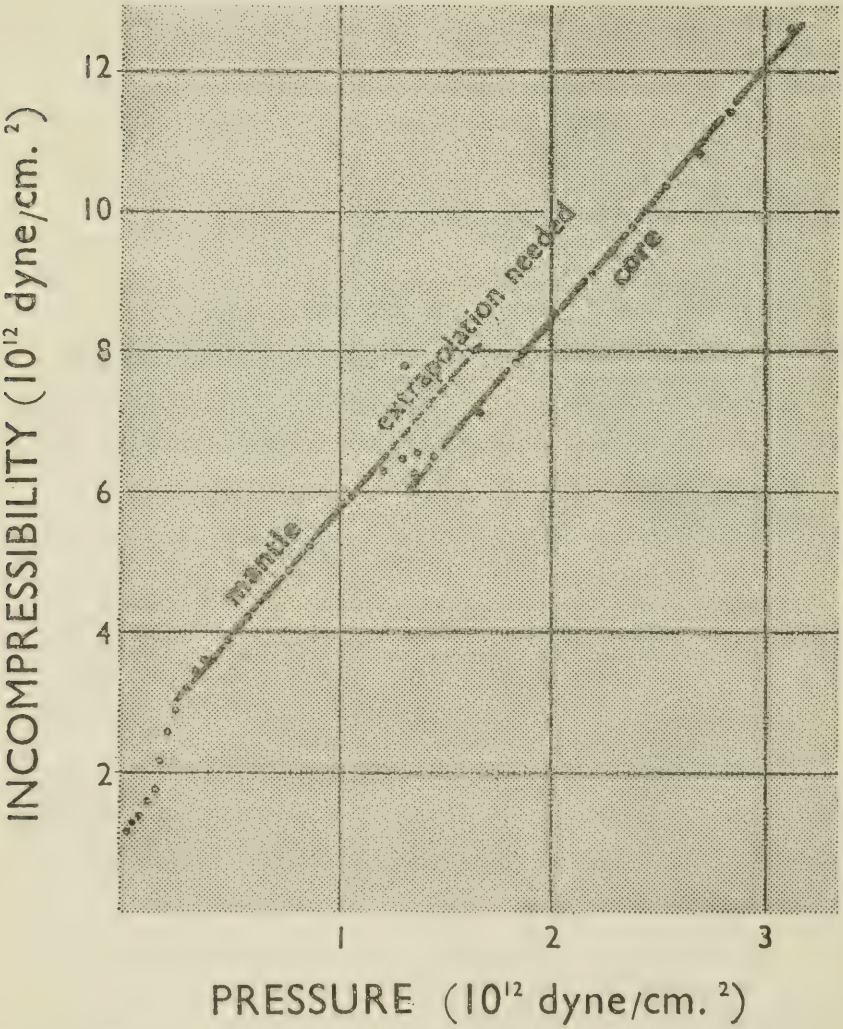

FIGURE 2.—The incompressibility of each of the Earth's three main zones is a linear function of pressure. But the greater compressibility of the liquid core means that as radioactive heating at great pressure causes more liquid to form, the Earth contracts. Where the outer shell meets the solid mantle, the pressure is 0.141 x 10^{12} dyne cm.$^{-2}$; at the boundary of the mantle and core, 1.36 x 10^{12} dyne cm.$^{-2}$; and at the Earth's center, about 3.9 x 10^{12} dyne cm.$^{-2}$; (10^{12} dyne cm.$^{-2}$ is approximately 1 million atmospheres).

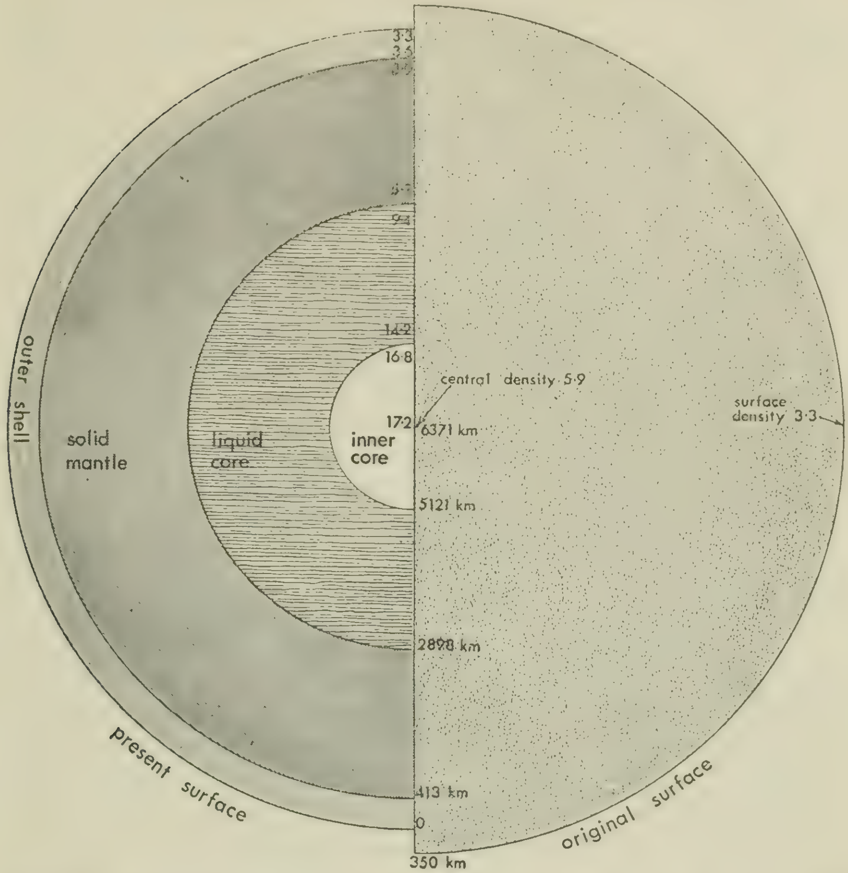

FIGURE 3.—The Earth's initial radius was about 350 kilometers greater than it is now. Its surface area must therefore have been reduced by about 60 million square kilometers. This additional material would have been tucked away by folding and thrusting, giving rise to epochs of mountain building which still continue.

HEATING AND CONTRACTION

But this is only the beginning of the story. We have also to explain how the Earth has come to possess its liquid central core, with a radius more than half that of the Earth. Clearly something must have happened to raise the temperature enough to cause the Earth to melt. There is no difficulty here, however, for this could be achieved by only a minute content of radioactive materials: no more than a few percent of the proportion found to be present near the Earth's surface would gradually raise the temperature as these materials—mainly uranium, thorium, and potassium—decayed into other elements, thereby releasing energy. Thus, instead of the Earth cooling down, it has in fact been warming up and is still probably doing so. It may well have remained entirely solid for a thousand million years or more, until the

central temperature reached the melting point of the material there: this would mark the beginning of the growth of the core. Further release of radioactive energy would increase the temperature, and the core would continue to extend further out.

The crucial point is that this liquid form, which the material is converted into as a result of both the high pressure and temperature, is more compressible than the solid form constituting the mantle. Thus, as the core mass increases, the Earth gradually gets smaller. Over the whole age of the Earth, the average rate of decrease of the outer radius has been about one-tenth of a millimeter a year—in 3.5×10^9 years this amounts to 350 kilometers. This contraction also releases gravitational energy, which will augment the heating by radioactive energy, but in a planet as small as the Earth this additional source of heat cannot be tapped until radioactive heating has first produced liquefaction, so that contraction can begin.

An indirect consequence of the gradual contraction would be that the rotation of the Earth would have speeded up: the rotatory inertia of the planet would have decreased as the body contracted. It now has only about 4/5 of the original value, and so the present angular velocity would be about 5/4 of the original rate in order to conserve rotatory momentum. This means that the day, if affected by this process only, would initially have been about 30 hours long. It is known that the tides of the sun and moon act to slow the Earth down, but the present process appears to be of comparable importance, and it will need to be taken into account in future discussions of the evolution of the Earth's rotation.

STRAIN, FRACTURE, BUCKLING

It is the response of the outer layers of the Earth to this steady liquefaction of the deep interior that is ultimately responsible for the formation of mountains. But the surface does not follow the contraction entirely uniformly because the strengths of the materials in the outer few kilometers are greater than the pressure. Thus the contraction in the core for a time produces no catastrophic effect at the surface, but only builds up increasing strains. Rocks can be compressed by rather more than one part in a thousand of their linear dimensions before they yield altogether and fracture. Thus a spherical Earth could contract down by a few kilometers without serious distortion at the surface, but then any further contraction would result in widespread fracture and buckling of the outer layers. Some catastrophic readjustments would be made as the material gave way under excess strains. This stage would correspond to a period of mountain building. What exactly would take place in any such catastrophic epoch is almost impossible to consider theoretically, for the Earth's surface layers will have different strengths at different parts,

and the processes will automatically always find the weakest parts of the planet's crust.

It is unlikely that the mountains were produced exactly in their present forms. Long ridges would develop where one layer was thrust over another, and then erosion would carve out gorges and canyons by wearing away huge quantities of the more readily removable material (*see* pl. 2). The resulting reduction in weight would cause the whole area gradually to rise, maintaining a kind of floating equilibrium on the layers below. This would increase the surface irregularity, though clearly there is a limit to which the process could go. Similarly, where the relief of stresses took the form of folding of the surface layers, subsequent erosion would accentuate the surface features, at least for a time.

THE EARTH'S STORY IN OUTLINE

Thus it now seems probable that the Earth began as a cool featureless planet with minute traces of radioactive minerals spread through its volume. Aeons may have passed while the internal temperature slowly but inexorably rose, until suddenly the crucial melting point at the center was reached and the process of contraction was set in motion. Compression of the liquefied central part would take place automatically at this stage because of the high pressure, and the outer parts would then follow down to restore equilibrium. Continuing compression would begin the cycle of mountain formation by building up stresses in the outer layers. This would be followed eventually by catastrophic release as the surface rocks folded and fractured, and erosion of the resulting foldings and thrustings would finally produce huge areas of mountain ranges. And there is no reason to suppose that the process has ceased: the lifetimes of radioactive elements are such that heat is still being produced throughout the Earth, though certainly at only a fraction of the original rate. But until it practically ceases altogether, the Earth will go on contracting and periods of mountain building will continue to occur.

MOUNTAINS ON OTHER PLANETS?

To the question: could mountains be formed by this process on the moon or on any of the small planets, such as Mercury, Venus, or Mars, the theory can in fact give quite definite answers. Venus, for example, has an observed radius consistent with the value it would have if the planet is made of material with similar properties to the Earth. Since its mass is only a little less than that of the Earth, the internal conditions of pressure and temperature are likely to be such that melting near the center has occurred, and a liquid core formed deep within it, but not to quite the same extent as in the Earth. Folded and thrusted mountains would therefore be expected to be found on Venus.

Mars, on the other hand, is only about one-ninth the mass of the Earth, and not only would the temperatures due to radioactive heating at corresponding depths be rather less than in the Earth, but the pressures are far too low for liquefaction yet to have occurred in its central regions. So no contraction of Mars can have occurred: indeed, if anything has happened as a result of internal heating, it would rather have produced very slight expansion of the outer parts, possibly thereby bringing about rifting of the solid surface. Whether such riftings could be eroded into anything resembling terrestrial mountains is doubtful. Although the surface is directly visible, Mars is rather too distant for the question to be settled for certain at present. Nevertheless it has long been believed from observations near the edge of the planet's disk that there can be no irregularities of more than a few thousand feet, and the absence of detectable shadows means there is no direct evidence even for this amount. Photographic or other kinds of survey from space probes passing close to the planet may clarify the situation in the next few years.

The same conclusion holds for both Mercury and the moon, and the theory indicates that these bodies have always been solid throughout. Hence no mountains of the terrestrial kind can be expected at their surfaces. It is of course generally recognized that no such features are to be found on the lunar surface; all the so-called "mountains" can be associated with the remnants of the rims of large craters that have been heavily eroded.

However, special processes, perhaps chemical or radioactive, might lead to the development of intense local heating in comparatively small regions of the outer parts of the planets or of the moon. For example, a large meteorite of high radioactive content plunging into a planet might produce sufficient heating to bring about volcanic effects hundreds of millions of years later. This in turn could lead to the building up of volcanic mountains, but these make an almost negligible contribution to the whole area of the Earth covered by mountains.

We can conclude that if the inner planets began as molten bodies, they should all possess mountains produced by thermal contraction. But if they began as entirely cool bodies, only the Earth and Venus can have mountains. Thus we have an absolutely clear-cut test of a new hypothesis which implies a great deal about the deep interiors of the planets—a realm that can be explored theoretically. And there is an intriguing opportunity for space research to obtain the necessary evidence by direct exploration of the surfaces of these planets.

The Future of Oceanography[1]

By Athelstan Spilhaus

Dean of the Institute of Technology
University of Minnesota

[With 4 plates]

Oceanography's future depends on the uses to which we put the ocean. The science of oceanography is not a discipline but an adventure wherein any discipline or combination of disciplines may be focused on understanding and using the sea and all that is in it. Often the arts of using the sea precede the full understanding of it and point to questions yet unanswered. For example, submarines led to the study of how sound travels in the ocean; aircraft carriers to the study of waves. But equally, scientific discoveries resulting from sheer curiosity point the way to new uses. The finding (first by the *Challenger*) of manganese nodules on the bottom of the sea, followed by recent photographs showing their abundance, has led to serious work on "surface" mining the sea bottom. In all science there is a continuous interplay between artisan and scientist; in oceanography, it is between sailor, submariner, fisherman, and oceanographer.

So, to speculate about oceanography's future, we must extend present uses into the future, dream of entirely new uses, and see what we can do to bring them about.

One of the first and still one of the foremost uses man makes of the ocean is as a magnificent highway with "straight," great circle routes to travel from any point on the coast of the world island to any other point on its coast. Surface navigation has been highly developed with excellent "road signs" from the simplest buoy or lighthouse through radio time signals, sonar, long-range radar, and radio direction-finding navigational aids, to the most modern systems of navigation utilizing the navigational satellite as a "lighthouse in the sky." Here, as in all cases, the needs for pure, scientific oceanography, for industrial exploitation, and for the Navy are parallel. It is no use for the oceanographer to know in detail the character of a certain body

[1] Reprinted by permission from *Ocean Sciences*, edited by E. John Long. Copyright 1964 by U.S. Naval Institute, Annapolis, Md.

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of water, the currents, or the nature of the ocean bottom there if he does not know precisely where "there" is. Now that the Polaris missile can be launched from the sea, the Navy must also know the exact launching point in order to aim.

Navigation of the future will be done more and more under water. Although submarines have thus far been used principally for military purposes, the advantages of traveling below the disturbed interface between ocean and atmosphere with its waves, windstorms, and ice mean that submarine freight and passenger travel, as well as a variety of submarine vessels for research purposes, will undoubtedly be developed. Under water the navigational problems are even greater. The navigator must have complete maps of the bottom topography, the gravimetry, magnetic anomalies, and the nature of the sea bottom. He must have instruments to detect these so that he may "see" where he is just as a land or air traveler sees his position on ordinary maps. He will also, for regular routes, have a beacon system under the sea, as airplanes have in the air; thus, he will home from beacon to beacon.

The other age-old use that men have made of the sea is to gather their food from it. It is not immediately obvious that studies of life in the sea are important to the Navy, but in fact, the Navy has given considerable support to work in marine biology. Two obvious examples of direct naval significance are research on marine fouling organisms and the noises that animals make in the sea that confuse hydrophone listening. Unquestionably, studies of life in the sea will find increasing importance, not only for the needs of people in peacetime but also for military applications.

Food from the sea is not properly exploited. On the one hand, some desirable species of fish are overfished to the extent of threatening extermination; on the other hand, some are not used at all. Countries having ample food within their land boundaries, such as the United States, use less fish than heavily populated countries surrounded by the sea, such as Japan. Only 5 percent of our protein comes from the sea as compared to the world average of 12 percent. This world average must inevitably increase with population growth. There are other factors which affect the use of protein from the sea. Even in protein-poor countries such as India, abundant fish from the Indian Ocean are not extensively used. This is partly due to the difficulty of preserving fish without expensive refrigeration in hot lands. Modern canning and dehydration can surmount these difficulties. Education to overcome taboos and use protein-rich, nonspoilable fish flour can provide the necessary supplement to the diet of one-fourth of the world's population which is undernourished now.

If we harvested this renewable source of food properly, we do not know whether we could steadily take five times the present amount out of the sea or a hundred times that amount. Marine biological and

fishery research must give us an estimate of productivity which would let us plan the size of the harvest so that it would be constantly conserved and renewed, at the same time it is being used.

But, once we establish the present productivity of the sea, we need not stop there. Agriculture on land has made tremendous increases in productivity per acre by growing single stands instead of mixed populations, by breeding special strains adapted to a particular locality and resistent to disease, by renewing the land by plowing, fertilizing, and irrigating. All of these methods have their counterparts in aquaculture, the farming of the sea. Behavioral research on marine animals' reactions to stimuli— electrical, acoustical, chemical, physical bubbles and currents, and temperatures—all point the way to the kind of "fences" we may use to isolate species and special breeds and harvest them more readily than do present fishermen who merely hunt them.

The nutrients needed by life in the sea are presently renewed and concentrated by various processes of nature. When we understand these, we may be able to emulate them in artificial processes. Winds drive away surface water in the lee of a coast, bringing up nutrient-rich lower water. This suggests that barriers placed in the open ocean might form artificial lees with rich patches of water around them. In the open ocean when winds diverge, they also bring up bottom water at the center of the divergence, and the natural stirring of currents plows the sea. Perhaps we can "boil up" the nutrient-rich bottom water by putting a nuclear stove down there. Possibly the waste heat of an underwater nuclear powerplant for submarine beacons for navigation could be used for this. Without aquaculture, the problem in the sea is similar to the problem of gathering food from the wild mixed animal and plant life in the undeveloped tropics. It is simply that the desirable foodstuffs, plant or animal, are widely scattered and hard to gather. Some way must be found to concentrate or herd them. We shall need "shepherds" and "cowboys" in the sea. Perhaps they will ride bucking one-man submarines, or perhaps as a result of the present behavioral studies, we can train dolphins as sheep dogs of the sea.

The difference between wild scrub cattle and the highly bred, heavy beef cattle is a result of selective breeding, good pasturage, and supplemented feeding. Fish husbandry can do the same for fish in isolated areas of the sea.

Present-day fishing methods are mainly of two types, either netting fish, which are closely gathered in schools, or hooking them with bait. How fish respond to stimuli points the way to powerful new methods of fishing and shows that the fish will line up and swim toward one pole in a field of electric current. "Electric fishing," already practical in fresh water, requires greater currents in the ocean water electrolyte;

but pulses of high energy may soon be used to make fish swim straight into a funnel hose, thence to be pumped directly into the hold of the factory ship. The most important sense a fish has is its chemical sense, and this may be exploited by ringing a school with a repellant to concentrate it and then luring it to an attracting chemical. Finally, the fish may be rendered senseless by another chemical and swept from the surface of the sea. They can be processed immediately in floating factories which will look more like chemical engineering plants than ships as we know them today. Around these factory ships, cities will grow, especially in the most productive waters of the world such as the Humboldt Current and Antarctic waters. The cities will be made up of apartment ships with shopping centers, having protected sea gardens between them, and airport ships. And, as other extensions of the floating city grow, perhaps even "municipal" hydrofoil transportation will be needed.

Even more archaic than the primitive state of present day fishing is the way we use (or don't use) the vegetation of the sea. It is true that peoples in Asia use seaweed as an important part of their diet, and in Japan it is grown on fences for ease of harvesting; but in our country we use it only as a source of algin in ice cream, cosmetics, and jellies. Surely just as the grasses of the land were developed to yield the wheat, corn, barley, rice, rye, oats, and even sugar for our daily bread, seaweed can be cultivated to form an important part of our food.

Even the useless poisonous living plants and animals in the sea may be put to use. They are sources of important drugs, antibiotics, and tranquilizers. We may separate the poisons from hideous sea cucumbers and stingrays for our medicine cabinet and eat the rest.

The most important need of life that comes to us from the sea is fresh water, distilled naturally by the sun, condensed into rain or snow and carried onto our lands. Until very recently the importance of this sea resource was hardly appreciated because of its abundance. Now, however, lack of fresh water is often the one critical factor not only in the support of peoples in arid and semiarid lands, but also in modern cities. Methods of producing fresh water artificially from brackish or sea water are being vigorously pursued, and without question, this will be a big industry of the future. As technology advances, the cost of separating fresh water from salt will go down. As population increases, the value of fresh water goes up. When these two curves meet, the process is "economical." In parts of the world, such as the oil towns of Arabia and isolated naval base islands in the Pacific, they have already crossed.

Half a dozen radically different methods of obtaining fresh water from the sea are now being tried. Distillation, emulating the natural way the sun makes fresh water, is one which may not turn out to be the most practical unless abundant solar or cheap nuclear power can

be used. Freezing of sea water in nature leaves about one-third of the salts in pockets in the ice, but the technique of zone refining of metals which results in ultra purity suggests the method of "zone" freezing, which would have the advantage over distillation in that it requires only about one-sixth of the power. Semipermeable membranes, ion exchange, and even salt-eating bacteria are other possibilities.

As the need for fresh water increases, more and more rivers will be stopped from running into the sea. This does not mean that the rivers will cease to exist, but simply that their waters will be used and reused and returned to the sea through the evaporative cycle rather than by waste flow. Every drop of fresh water that flows into the sea represents a waste of the solar energy that was used to distill it. The rivers of the world carry 2,000 million tons of salt each year into the oceans, and one might think that by tampering with river flow we would upset the balance of ocean salts. But to give an idea of how tiny this effect is, the annual amount of salt going into the sea is only one hundred-millionth of the total already there.

As well as producing fresh water for use on land, we will develop ways of producing it under the sea. This is done now by evaporation in the nuclear submarines, as it is indeed on surface vessels. When we understand how penguins can exist without a drop of fresh water and exclude the excess salt, perhaps we can build counterparts of their mechanism to get fresh water.

Before man required fresh water from the sea, he needed just the opposite—to extract the salt. This is an ancient art; at first the salt was used only for the seasoning of food. But in the last 40 years, not only have sodium, potassium, and magnesium salts been extracted economically, but also bromine and magnesium metal. The difficulty of getting anything out of sea water is that everything occurs in a highly dilute state, and large amounts of water have to be pumped and processed. But power is getting cheaper, and perhaps, instead of pumping sea water through plants on land, we will have floating processing plants at sea, propelling themselves through the water as they take what they need from it, just as marine animals do. The advantage of such floating "refineries" is that they do not occupy expensive shore land and can move to areas of rich sea "ore." Perhaps deuterium taken from the sea water itself will power them.

Many valuable elements are so dilute that it is not economical to extract them from sea water, yet nature concentrates them in high-grade deposits on the floor of the sea. Nodules on the sea bottom are already being mined for phosphorus, and nodules of manganese, not valuable enough in itself, may contain enough valuable nickel, cobalt, molybdenum, and zirconium to warrant scraping them off the bottom in a deep sea mining enterprise. The most interesting facet of this

deep sea mining is that the nodules seem to form at a rate exceeding what we might conceivably take out to cover the present total world consumption of these metals. They are like self-renewing mines.

As time goes on, other valuable materials may be discovered on the bottom of the sea. Already, off Southwest Africa, a company is recovering diamonds. They are hopeful of getting 75,000 carats a month in sizes up to 10 carats. But the nodules and diamonds are just a start; undersea prospecting has hardly begun.

It is not surprising that we now drill for oil under the sea on the continental shelves which are merely extensions of the land, the shoreline being an accident of present sea level. We should therefore expect that, as our ability to drill in deeper water increases, oil rigs will push farther and farther off shore.

Exploitation of all of these things we need from the sea for living will inevitably lead to international disagreements and then, we hope, to agreements surrounding the "ownership" of the oceans.

Parts of the edges of the ocean must be exempt from exploitation of any kind and must be saved for two other uses. First, for scientific purposes as well as aesthetic, we must have some land, estuarian water, sea, and island communities preserved in their natural state. If we do not do this soon, the whole coast of the United States will be bulkheaded with concrete by well-meaning engineers to prevent the "ravages" of wind and wave. All our estuaries will be filled to make "valuable" shoreline property. Tidal estuaries will be polluted. These and other competitive uses will destroy our valuable seashore and leave none in its natural state. Furthermore, as fishing methods become more efficient, sport fishing even more than commercial fishing, unhampered by the cost of acquisition of aqualungs, guns, chemical lures, electronic fish calls, may deplete certain species. These same species may be the very ones that need the disappearing estuaries as nurseries for their larvae and young.

Secondly, men during their working lives must periodically take time for "recreation." As the land becomes more crowded and cities grow, men turn to the sea for holidays. This important use should not be forgotten among other competitive uses of the coastal seas. The same reasons have led us to set aside wilderness areas on land.

Mass-produced underwater vehicles within the reach of many will become as common as automobiles. Advances in underwater breathing gases and apparatus will make it possible for everyone to go down into the sea. Underwater resorts will develop. People will drive down under the sea, park their submobiles, check into submarines, and participate in one of the many recreations the resort will offer. Like land resorts, the ideal undersea resorts will be in clear, warm water regions—Florida, the Bahamas, across the Antilles, Hawaii, the Pacific islands, and similar areas. Submarine trains and guided tours will

take people through the reefs and underwater world so different from their normal environment. Underwater hunting and photography will become ever more popular sports.

One of the best means of averting war is complete surveillance. If peoples and nations make their moves openly, exposed to the vigilant eyes of their world neighbors, there is less chance of conflict. This is the basic reason for developing surveillance systems on land and in the air. It is equally valid for the sea. Fixed defenses, such as mines and bottom-moored weapons, are tremendously effective, but because of international ownership of the sea, in times of peace, they cannot be placed unless it is covertly done. This is very different from the pre-aimed intercontinental ballistic missile silos that stand ready on home land.

Until the time comes when we have complete surveillance in the sea, the first military task for submariners is to "see" yet be "unseen." And all the developments of sonar and the silencing of submarine weapons and vessels are toward this end. The second important military objective is to go deeper in the sea than your enemy. In fights between aircraft, the one that could climb higher had the advantage. First rockets, and now satellites, have virtually removed any ceiling. In the sea, the only way to be sure the enemy cannot get below us is for our submarines to be able to go to the deepest part of the ocean.

But speed is as important as depth. All submarines up to the present time have been built with positive buoyancy so that if the engines failed or were shut off, they could float directly to the surface. Perhaps this idea should be abandoned, as it was with aircraft when we moved from the floating dirigible to the dynamically supported airplane. Pencillike submarines with negative buoyancy might have the strength and streamlining for the necessary depth with speed. They would rely on the dynamical lift of their hydrofoils with the reliability of their motors to raise them from the deeps. The third point is to know where you are. This has been satisfied by the submarines' new navigational aids. The fourth military consideration is to be able to hit what you aim at. It is incredible that the United States can guide a probe to the vicinity of Venus, yet not be sure of hitting a target from a submarine a mile away.

The ocean engineering of submarine travel, research, exploitation of the sea, and living in or upon it does not, for the most part involve new inventions. The elements are now known. A vehicle *can* be built to take us anywhere in the sea, even 7 miles down. We know how to build the structures and how to arrange communications. These new engineering products will emerge just as soon as research, defense, or industrial needs demand and justify them economically.

Flip, the ship that goes to sea and then submerges its stern with just the bow peeking out of water as a floating station, can easily have

a bathyspherelike elevator built into its stern so that, once in position, investigators or workers can go down to the bottom or any intermediate level by elevator and return home to *Flip* when their work is done.

The extraordinary success of the early attempts to drill toward the earth's mantle—the MOHO project—will for scientific reasons, if no other, make drilling the ocean bottom another routine survey procedure. Instead of drilling from a rig floating on the hazardous, wavy, stormy surface of the sea, with a threadlike string twisting through miles of water before reaching the drill, the rig, power, and everything will in the future be located on the bottom.

It is most exciting for the scientist to explore the bottom of the sea, because it has preserved the history of the earth in the layerings of its sediments without the weathering, folding, and creasing of the pages that occurs on land. Perhaps the best place to estimate the quantities and recover the materials—meteorites—which come to the earth from space is the undisturbed bottom of the sea.

When we have blue-green lasers, possibly with choppers to reduce backscattering, we will be able to see and photograph through the sea water "window" a greater distance. Self-perpetuating ocean power sources will be developed; some will generate electricity by biological means using bacterial anodes and cathodes. Missiles for the exploration of space or other uses may be launched more cheaply from "silos" in the sea. Undersea pipelines, already well developed, may carry all kinds of fluids or fluidized substances under the sea with less maintenance than land pipelines. Submarine freight transport may be far more practical than surface vessels adversely affected by storm and wind, and more economical than air freight because of the buoyancy of sea water.

Transit-type satellites have already proved their worth for navigation at sea, but this is just a beginning. Satellites can be used to collect and retransmit data from buoys and ships at sea, to take pictures of ice conditions near the poles, by infrared sensing to trace ocean currents by the differences of temperature, and even for tracking the worldwide migration of certain sea animals with transmitters attached.

In the air we are accustomed to breathe, the inert gas nitrogen dilutes our oxygen supply. Some of the most exciting experiments are those that show that, for underwater breathing at high pressures, other inert gases are superior, and various mixtures have been tried with some success to prolong the length of time and the depths at which men may stay under water. Extension of this research will show us how to "condition" the air for underwater resorts, underwater military establishments to service true submarines, and for cities if we are driven to the protection of the sea to survive atomic attack. It is

not out of the question that some, perhaps at first clumsy, large replica of the natural mechanism by which fish extract oxygen from sea water through their gills may be made and used by men under the sea.

Oceanography is moving rapidly away from the expedition stage. Already there are the multi-ship efforts to get a synoptic or bird's-eye view of changing current systems and interest in moored buoys as observing stations. Ultimately, all over the oceans, we must have a permanent network of stations observing and reporting conditions on the surface and down to the bottom. This would be a counterpart of the worldwide weather network which observes conditions on the earth and high in the atmosphere. This network of stations will consist of manned and unmanned buoys and artificial islands on reefs and seamounts close to the surface. Surface ships and submarine survey ships will routinely fill in the gaps between the permanent station network. Airplane and shore bases will be established for gathering data on ice and from automatic reporting buoys. A satellite network will receive, collect, and retransmit the worldwide synoptic ocean data to central storage, analysis, and forecasting computers in various countries.

The survey ships will need to have semiautomatic means of taking and processing the vast amount of data to feed it to the computing centers. We will need a census of living matter in the sea. We may count fish of different species by sonar, radio, chemical, or other distinguishing tags. We will need automatic methods for the preliminary sorting of microscopic plankton.

It is this kind of data which will develop ocean forecasting. The already accurate forecasting of tides will be extended to the prediction of tidal currents. Ice and iceberg distribution, growth, and melting will be foretold. The best channels for sound communication will be predicted, and forecasts of the varying strength of ocean currents, winds, and waves will indicate the safest and most advantageous course for ships. A worldwide fishery forecast both from observation of the distribution of fish and by inference from winds, currents, and physical conditions will tell us where the fish are. "Fish Futures" will be bought and sold as commodities on the basis of observations of each year's larvae and information as to when and if they will produce a good crop of 3-year-old or 4-year-old fish.

One of the more important outcomes of oceanographic forecasting will be its contribution to weather forecasting and even to seasonal and longer term predictions of climate.

The ocean's effect on climate is only understood in broad outline. With nuclear explosives, we have powerful earth-moving devices which put within the realm of possibility the actual blocking of straits, damming or diversion of warm or cold currents which could profoundly affect climates. In most cases, however, we do not even

know what the direction of change might be. For example, if warm water were pumped, as has been suggested, into the Arctic Basin through the Bering Strait, would the warming be beneficial or would so much more snow come to Canada as to reduce the habitable land area? With the observations from the oceanographic network and by varying certain factors put into the forecasting, we could conduct experiments to see what would happen before we try it.

Climate control by cloud seeding is more the province of the meteorologist, but anyone who has gone to sea knows how clouds hover over the edges of the Gulf Stream, for example. By influencing the reflectivity and absorptivity of the sea surface, or of sea ice in polar regions, we may be able to redistribute the clouds, even break up an area in the tropics which may be the breeding place of a hurricane. Or, alternatively, for offensive purposes, we might encourage the generation of the hurricane. Such control of weather can be used either way for warlike or peaceful purposes.

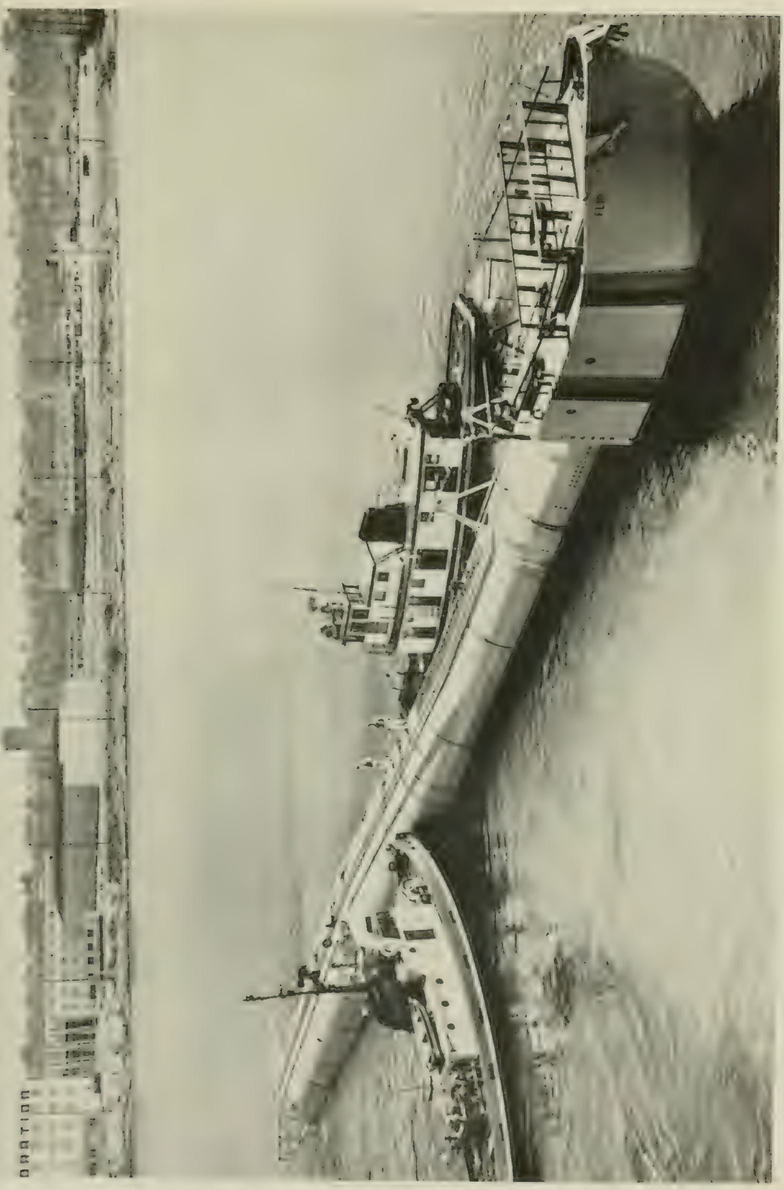
We may even speculate about control of whole seas. In special cases such as the Mediterranean, the connection to the deep Atlantic is blocked by a comparatively shallow sill, so the Mediterranean is nutrient poor because the inflow of the phophorus rich deeper Atlantic water is dammed. With controlled atomic explosives this dam might be removed, increasing the productivity of the whole Mediterranean Sea.

Just as we now accept complete surveillance as one of the important deterrents to war and have built elaborate air surveillance networks and are negotiationg for international seismological surveillance systems on land, so our sonar and other means of keeping track and identifying every vessel, surface or submarine, military or commercial, in the sea must be perfected. Perhaps international surveillance systems may come about by agreement between nations.

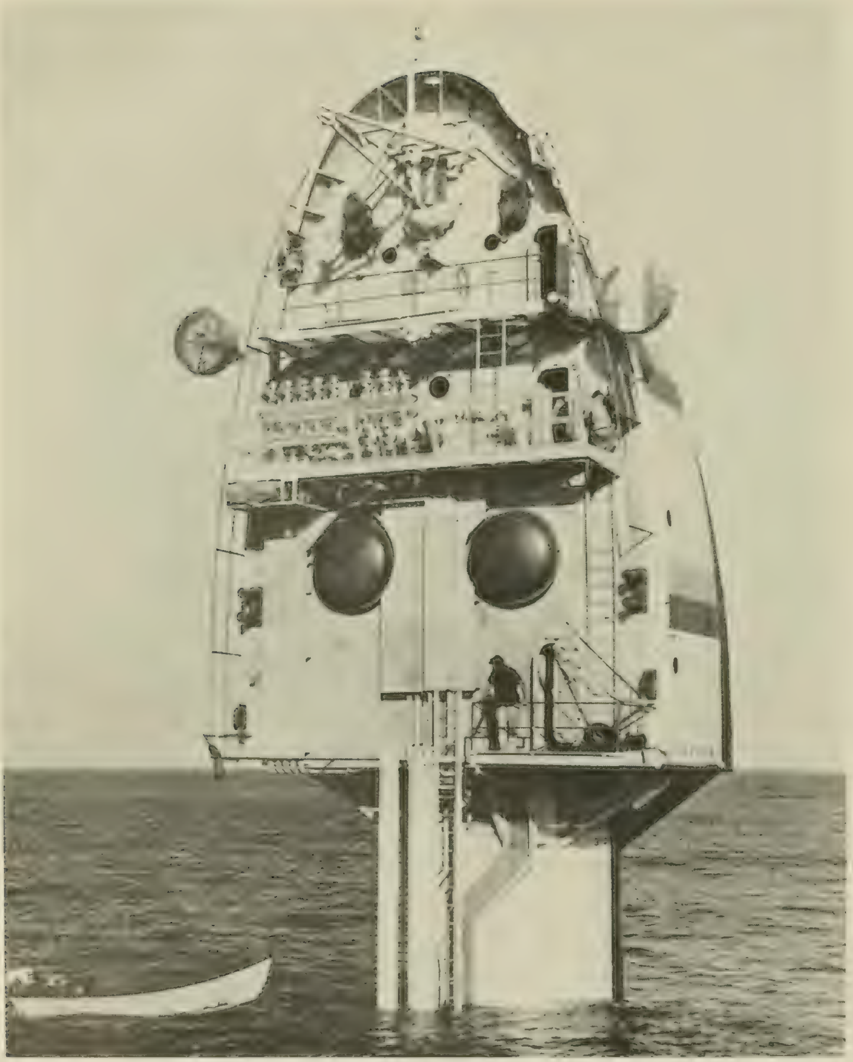
Oceanography has for many years set a pattern of international cooperation in studying the seas. The kind of survey work necessary to assess all marine resources is one that is too great for any one nation. It should be done internationally.

Another urgently needed international project in the oceans is to set aside presently uninhabited islands and their surrounding waters as *international* sea wilderness areas. Examples are Inaccessible and Nightingale Island in the Tristan da Cunha group, Bouvet in the South Atlantic, and numerous Pacific islands. This should be done soon so that the continuity of marine and sea bird wildlife may be preserved before the pressures of population cause the islands to be inhabited and thus upset the balance of these last natural sanctuaries.

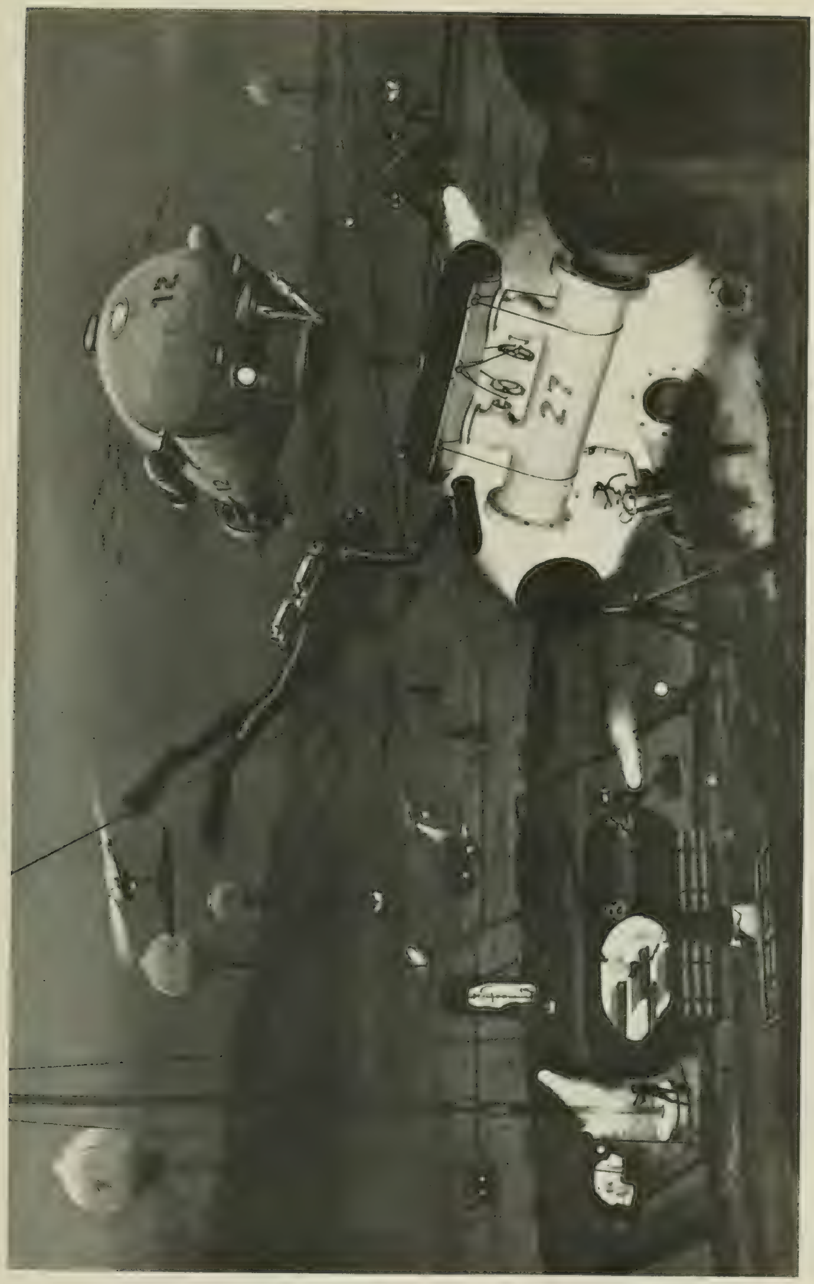
The freedom of the seas has been jealousy preserved over the ages. But as we take more from the sea, not just along our shorelines but from the open ocean, we shall need more international agreements,



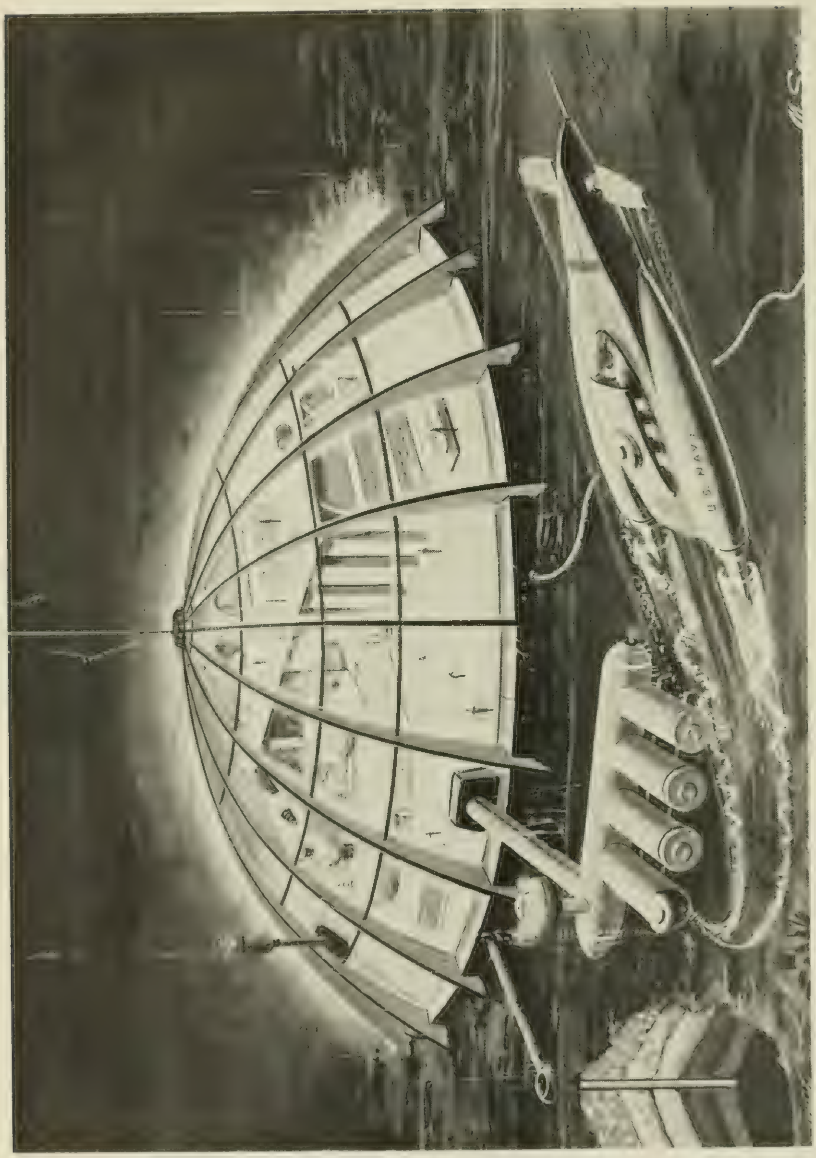
Perhaps one of the strangest of all modern oceanographic vessels is Scripps R/V FLIP, shown here after launching at Portland, Oreg. By flooding her stern, FLIP can become vertical in the water, providing a stable platform at sea.



New equipment was tested in Pacific waters by FLIP (Floating Instrument Platform) in September 1963. The 355-foot craft, when standing upright, moved hardly at all, even in heavy seas. It thus permits the use of sensitive oceanographic measurements. Enroute and return it is towed.



Adventurous divers tap an oil field far below the reach of surface drillers. Artist Pierre Mion translates the scientist's vision of future operations, perhaps 600 feet down along the continental shelf. The main pipeline would cross an ocean-floor plateau and then ascend to the shore.



This sketch by Marion Senyk—a "forecast for the seventies" depicts a future permanent underseas base, as oceanographic exploration becomes a naval activity of increasing scope and importance, and as burgeoning needs of civil life become more complex.

perhaps even the granting of rights for exploitation. When no single nation owns any parts of the ocean, then no nation worries about the conservation of its resources. Rights to exploit the oceans of the world should carry with them specific responsibilities for their conservation.

When amicable agreements are arrived at with respect to who takes what and where, we shall still need an international seaborne control force to see that these agreements are carried out. Hopefully, this force should resemble an international commission of game wardens or officials of a world bank of ocean economic resources rather than the familiar pattern of the more politically involved international organizations.

Much of this article has been mere speculation about oceanography's future. It is exciting to dream about some of the ways in which man may use the sea. But if the dreams are to come true, we must roll up our sleeves and make them come true.

Search for the *Thresher*[1]

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[With 4 plates]

On the morning of April 9, 1963, the nuclear-powered attack submarine *Thresher* steamed out of Portsmouth Navy Yard toward a nearby submarine operating area. Her purpose was to conduct the usual series of check dives which follow any major overhaul period for submarines of our Navy. With her, to provide escort and communication contact, was the rescue ship *Skylark*. As soon as the *Thresher* was clear of the shipyard, the crew rigged for dive and check-dived the boat in shallow water, following procedures developed over many years of submarine operations. At 0745 the following day, she sent her routine diving message to *Skylark* and to submarine force headquarters, then shortly after disappeared into the sea on her dive to test depth. About an hour and a half later a routine report was made by sonic telephone to the escorting ship—all was going well except for some minor difficulty. Then there was a more hasty, garbled report indicating more severe trouble; this was followed by noises resembling, it seemed to the sonar man on the *Skylark*, sounds associated with the breakup of a sinking ship. The *Thresher*, with all hands, was lost.

This ship (pl. 1, fig. 1) was the first of our Navy's newest class of attack submarines, the 15th nuclear-powered undersea craft of about 60 that have been in operation since the commissioning of the *Nautilus* in 1954. The number of innovations which have been brought to reality in these boats is so great that experienced submariners of World War II would scarcely recognize these craft as related to the wartime submarines except for the cylindrical hull and ballasting

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principles common to both. Speed, endurance when submerged, operating depth, search capability, and weapons effectiveness all have increased by factors unimagined 20 years ago. With these great improvements has come, with much less fanfare, though it is of comparable significance, an increase in safety of operation. Through all of the second-guessing as to the cause of the loss of this beautiful piece of machinery and its human crew, much has been said of measures which could have been taken to increase its structural integrity or its ability to respond under conditions of extreme stress, and even of a need to install special emergency data-recording equipment. The remarkable reality, however, and the reason for shock within the submarine forces, is that this loss terminated a 14-year period in which not a single U.S. submarine had been sunk. This is the longest such period since the introduction of these craft into our Navy in 1900, with the commissioning of the U.S.S. *Holland*. There has been a tendency to forget that duty in submarines is considered hazardous in the same sense that duty in military aircraft is. The shock engendered by the *Thresher* accident, in contrast to our acceptance of the loss of more lives in 1963 alone in military aircraft accidents than were lost aboard the *Thresher*, is a tribute to this new standard of operational safety.

The purpose of this article is, however, not to recount the various theories as to why this unfortunate event occurred or to discuss the engineering and construction improvements which it has triggered. Rather, we describe the participation of marine scientists and their tools in the search for the wreckage of this ship, which must eventually have found its way to the floor of the sea. Clearly, such a discussion must start with some consideration of why one might want to make such a search at all. There are several answers, each of which was pertinent to a different phase of the operation as it developed. At the very first there was a hope that perhaps the boat had not really gone down but had surfaced in the rough seas and, though crippled, might yet be found, or that some survivors might have escaped. This hope rapidly faded and was replaced by a determination to learn as much as possible for the future from the accident by photography, or perhaps even recovery, of parts of the hulk. Finally, as overoptimistic piecemeal adaptation of techniques showed that the location problem itself was a difficult one and that the craft had been catastrophically damaged, the emphasis shifted to the long-term problem of developing specialized equipment for careful examination of objects on the sea floor. In this last context the *Thresher* has become simply a good specific case on which to test the effectiveness of newly developing systems.

The marine scientific community was actively involved from the beginning of the first phase of operations. *Atlantis II*, the recently

completed research ship of the Woods Hole Oceanographic Institution, was at sea within 150 kilometers of the accident and immediately joined the destroyers, aircraft, submarines, and other Navy craft which responded to the emergency signals from the *Skylark*. The search initially was concentrated on effects observable at the surface, although the *Atlantis II* began use of its precision echo sounder early in the operation. The many ships plowed the area looking for slicks and debris, while the aircraft, in addition, surveyed the area with radiological monitoring equipment. Negative results with this equipment eliminated the fear that some reactor accident had occurred, with associated high-level contamination of the sea. As this phase developed it became clear not only that the boat was lost but that there was an uncertainty of several kilometers concerning the position of *Thresher* at the time of her last contact with the *Skylark*.

Determination to find the wreck in order to ascertain the cause of the disaster developed very quickly. During this same time the Navy began to realize that it had no operational techniques, in the conventional sense, adequate for the job. The Navy has, however, strongly supported research activity at sea, and thus had available a pool of interested scientists and research ships eager to assist with this new problem. Soon other research laboratories in the vicinity joined the search: Lamont Geological Observatory with its new (Navy-provided) ship *Conrad;* Hudson Laboratories with *Gibbs*, *Allegheny*, and *Mission Capistrano;* the Navy Research Laboratory, the Naval Oceanographic Office, and the Naval Ordnance Laboratory, working together, with another new research ship, *Gillis*, in addition to the *Rockville* and the *Prevail*.

Some organization of this effort was required, and for this purpose a seagoing unit was established—Task Group 89.7, under the command of Captain Frank Andrews, whose normal assignment was that of Commander Submarine Development Group Two, based at New London, Conn. Overall technical coordination was vested in the *Thresher* Advisory Group, under the direction of Arthur E. Maxwell, Office of Naval Research. This group included representatives from the laboratories mentioned above as well as from the University of Rhode Island School of Oceanography, the University of Miami Marine Laboratory, the Bureau of Ships, and the Office of the Chief of Naval Operations. The group met from time to time during the search to lay out plans and evaluate results. In addition, they were backed up by a full-time analysis staff assembled at Woods Hole and utilizing personnel from Woods Hole, the Navy Oceanographic Office, Submarine Development Group Two, the Naval Underwater Ordnance Station, and the Navy Electronics Laboratory.

Throughout this phase of the search there was a sense of urgency. Initially this was a residue of the urgency that characterized the ini-

tial effort, when there was a true need for emergency action. Later on, the feeling of pressure continued because all the major participants had previous plans for research expeditions, to which they were anxious to return. As time passed and the difficulties became more apparent, there was pressure to bring the operation to a successful conclusion before bad weather set in, in the fall.

The individual techniques which were immediately recognized as potentially useful and which were already being employed in some fashion in exploration of the sea floor were use of acoustic echo sounders or near-bottom sonar; magnetic, electric, radiation detection; photographic detection; real-time optical detection, either direct viewing or viewing by closed-circuit television from deep-operating craft; and dragging or dredging. The group rejected the last alternative, primarily on grounds that it would disturb the site in ways which might confuse interpretation of the situation when the wreck was found. Direct observation could not be implemented initially, but the bathyscaphe *Trieste* was immediately transported by ship from San Diego to Boston and readied for use.

Of the techniques available, the one which was most immediately and widely applicable was use of the precision echo sounder. This device consists of a downward-looking broad-beam sound transmitter and receiver; the received signal is displayed on a facsimile-type recorder having a very stable time base. This display produces, on an expanded scale if desired, an analog record of the echo return times for successive sound pulses transmitted into the water as the ship travels along. In normal use, this system provides an approximate representation of the topography for the construction of charts or the study of shapes of naturally occurring features. For search purposes this technique would be useful only if the sea floor were relatively smooth. If this were the case, attention would be directed to search for a small crescent-shaped pattern superposed on the echo returns from the sea floor. Simple geometry shows that the return from a submarine will be the first echo, even if the hulk is 150 meters to the side of the search ship's track, for target height of 10 meters in water depth of 2500 meters (about that in the search area). Comprehensive application of this technique thus dictated a stringent requirement for a navigational capability not normally possessed by research ships in this area.

SEARCH AREAS AND ACCURACY

The navigational problem was first met by the use of the Loran C electromagnetic system. After difficult-to-obtain Loran C receivers were obtained, it became rapidly apparent that the shore station locations were such that only one coordinate was useful. Therefore, arrangements were made to utilize, in addition, a Decca system in the

area, which provided another nearly orthogonal coordinte. Over a single weekend, new charts were prepared and receivers were provided for six ships. This system (combination Loran C and Decca), although it lacked accuracy at night, provided the primary navigational reference throughout the search. Reproducibility of position, as judged relative to bottom topography and moored buoys, was about 100 meters.

In the beginning of the operation the search area of 18 by 18 kilometers (10 by 10 nautical miles) was quartered, and one ship was assigned to each sector. With the availability of the improved navigational system it became apparent, however, that a more systematic approach was required. It was thus decided that four ships (*Allegheny*, *Mission Capistrano*, *Prevail*, and *Rockville*) would make a navigationally controlled, precision exploration of the entire area, with 250 meters between tracks, while *Conrad*, *Gillis*, and *Atlantis II* would move in to investigate possibly significant contacts. The systematic survey required 2 weeks of operating time in the area during which time the data were plotted and contoured aboard ship. The results provided the first quantitative indication of the difficulties of using the echo sounder for this purpose. A model showing the complexity of the topography is shown in plate 1, figure 2, in comparison with a model based on previously available data. The result was the conclusion that in about half the area the sea floor was too rough for search by this technique. In the other half there were six possible target indications, one of which was point "delta," first observed by *Atlantis II*. Because "delta" was close to the location deduced from the rough navigational record provided initially by *Skylark*, and because the echogram (pl. 2, fig. 1) was especially convincing, this point was given the highest priority for further investigation.

During the time the four ships were conducting their detailed sweep of the area, *Conrad*, *Atlantis II*, and *Gillis* had already begun investigation of the most likely locations. They relied principally on photographic equipment built over the years to solve the needs of submarine geologists. With such equipment it was possible to make stereo pair photographs of a strip about 7 to 10 meters wide, with overlapping coverage for successive exposures, while the vessel was traveling at speeds of 1 to 2 knots (1.8 to 3.6 km/hr). Aside from the resulting very slow search rate (about 2½ km.^{2} per week), this technique has the additional disadvantage of requiring a bottom-referenced navigation system accurate to within at least 5 meters to assure that there are no appreciable gaps in coverage. As an investigative tool in a restricted area, however, this is an essential method, since it can provide the detailed view of a wreck that is needed by investigators.

Underwater television was another device with similar restrictions that was available for optical investigation of the area. At the time

of the *Thresher* sinking, the Navy Research Laboratory had under test a slow-scan underwater television system. It was being developed by the laboratory for direct observation of the bottom in real time, to correlate with acoustic reflection measurements, as well as for examination of instruments and structures emplaced on and in the bottom. The unit had been tested through 6,700 meters of cable on the dock, but had never been to sea or even in the water. By accelerating the development program, the system was readied for use aboard the *Gillis* in May. Although the television had an advantage over photography in providing real-time observations (one picture every 2 seconds), it had a relatively poor 600-line resolution. Fortunately, the cameras could be activated to give pictures of better resolution when interesting objects came into view on the tube. Many thousands of "looks" at the bottom were obtained by this technique, complementing the results obtained by photography.

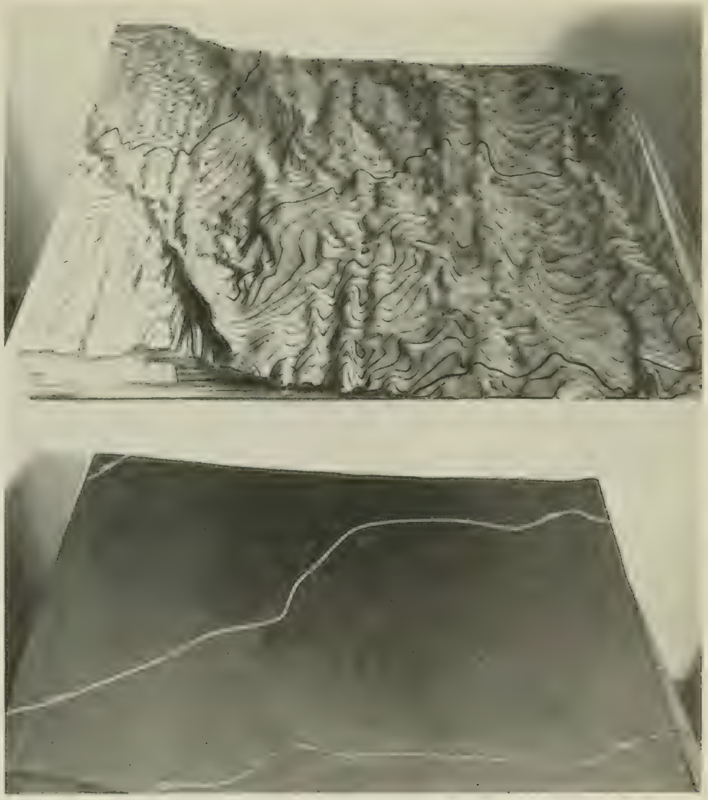
DEBRIS IS PHOTOGRAPHED

In spite of lack of knowledge of the exact location of the photographic or television camera (on the end of 2,500 meters of wire) relative to a lump on the sea bottom that had been found by the echo sounder at the surface, the ships criss-crossed the area with some success. Using combined photographic, echo ranging, electric potential, and radioactive equipment, part of which was loaned to Woods Hole by Schlumberger, the *Atlantis II* searched in a predominantly north-south pattern based on *Thresher*'s last known course of 090 degrees, in the hope that some evidence of her passage might be detected. This strategy paid off with the receipt of the first pictures of fresh man-made materials on the sea floor, and was used by other ships to build up, gradually, sufficient evidence to indicate a streak of debris about 1,000 meters wide and at least 4,000 meters long. However, none of the pieces of debris photographed at this stage showed any item clearly identifiable as belonging uniquely to *Thresher*.

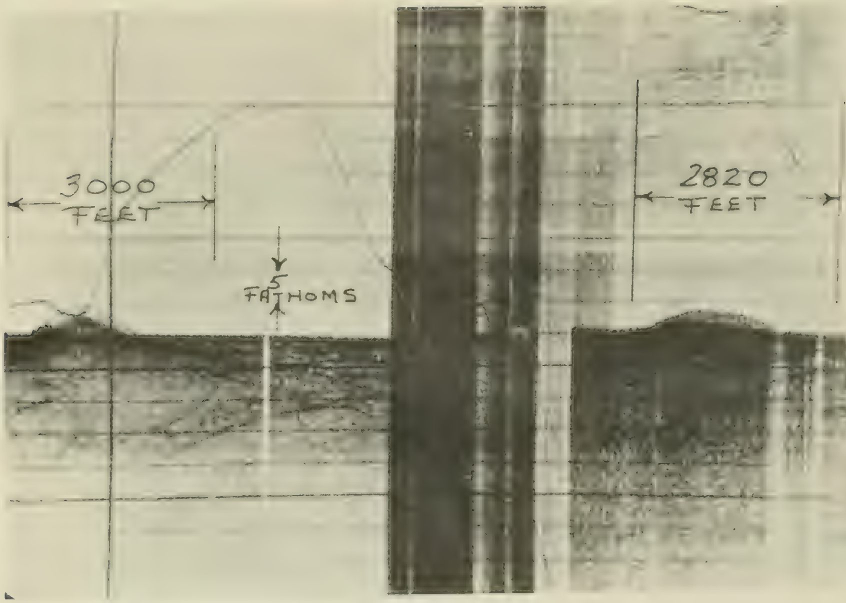
At this time the need to identify the debris streak with *Thresher* became strong enough to override, temporarily, the earlier restriction against dredging. *Conrad* had on board equipment normally used to gather rock samples from the sea floor. She dragged this across the debris area and, in several passes, recovered some envelopes containing spare gaskets. These were identified, from notes on the envelopes, as being definitely from the interior of the *Thresher*. Similarly, the *Atlantis II* dredged up pieces of battery plates that were later identified, by chemical analysis, as being of the type carried on nuclear submarines.

Dredging, photography, and echo sounding were three techniques which could be used in this search without any modification. Magnetometers [obviously applicable in a search for a 3,000-ton (2,700-

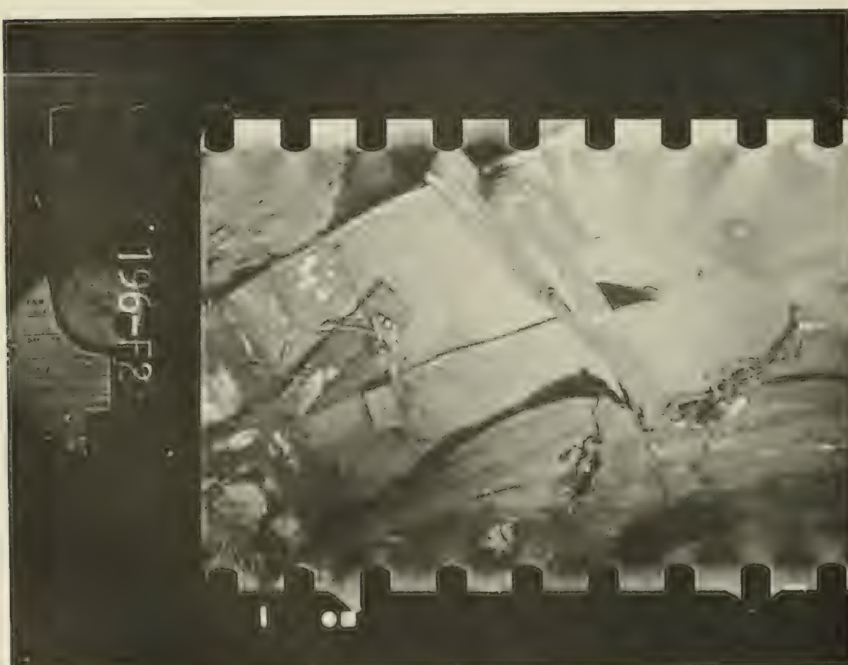
1. The bow of the U.S.S. *Thresher*. (Courtesy U.S. Navy.)



2. Two models, prepared by the Hudson Laboratories from echograms, of the topography of the sea floor in the area of the *Thresher*. (*Top*) Model prepared from data obtained during last summer's search. (*Bottom*) Model prepared from data available before the search. The three light lines in the model at the bottom correspond to the accented lines in the model at top. There are not only differences in detail but significant difference in the absolute depths. (Courtesy U.S. Navy.)



1. Two PGR (precision graph recorder) records taken from *Atlantis II*, showing point "delta." Because of the size and shape of this contact an accelerated search for the *Thresher* was made in this area. The first photographs of debris were obtained about 1 kilometer to the north. (Courtesy Woods Hole Oceanographic Institution.)



2. Photograph of debris from the *Thresher*, taken by the Navy Electronics Laboratory bathyscaphe *Trieste*, on August 24, 1963, at a depth of 2,600 meters. (Courtesy U.S. Navy.)

An attempt was made by the Navy Research Laboratory to integrate several sensors into a single streamlined package. This unit contained a side-looking sonar, a television camera, a photographic camera, a proton precession magnetometer, and a pinger to determine the depth of the unit above bottom. (Courtesy U.S. Navy.)

Exterior of the unit described in plate 3, showing the sensing element of the magnetometer mounted on the extended boom. (Courtesy U.S. Navy.)

metric-ton) lump of iron] had been used for geophysical exploration both on land and at sea, but usually as airborne or shallow-towed instruments. Only the geophysical group at Cambridge University, England, had a magnetometer capable of being towed at great depth, and this particular instrument was then in use in the Indian Ocean. Several laboratories (Lamont, Scripps Institution of Oceanography, and the Naval Ordnance Laboratory) thus began packaging the available magnetometers for use at depths which would give the required proximity (about 200 meters) to the hulk during search. More was involved than simple provision of a pressure-proof case; also required were a strong towing wire having good capability as a conductor of an electrical signal and proper telemetering circuitry to make the signal available on the towing ship. In early attempts there were many electrical problems. Nevertheless, one credible anomaly was found, at about the time of the dredging operations, but it was apparently remote from the debris area by more than a kilometer. Somewhat later, another signal (fig. 1) was found, several times, by *Conrad*. Still later this magnetic signal was confirmed by both *Gibbs* and *Gillis* (with equipment from Scripps and the Naval Research Laboratory). In each instance, navigational uncertainty and lack of ability to make photographs or view by television at the time the signal was obtained precluded the possibility of identifying these signals with *Thresher*, or even of being sure that they were all generated by the same object. The amplitude and dimensions of the signals were such that it is highly probable that they were generated by a mass of iron of the approximate dimension of a submarine, but whether this was *Thresher*, some other wreck, or even natural background is as yet not known.

High-resolution acoustic techniques, used near the sea floor, were regarded from the start as providing a most promising type of search. Two units were assembled through modification of existing equipment (by Marine Physical Laboratory and Woods Hole Oceanographic Institution), but these units lacked adequate resolution in angle. Westinghouse, under contract with Hudson Laboratories, built a unit specifically designed for the purpose, and it was operating effectively by July. This unit was towed near bottom, by means of a cable similar to that used with the magnetometers; it had an acoustic transmitter and receiver whose two narrow beams were directed one to each side. The variation in amplitude of the nearly continuous sea-floor reverberation from each transmitted pulse was plotted on a facsimile-type recorder. In this way, for each pulse a high-intensity mark was made at the ranges of highly reflecting sea-floor features and virtually no intensity was recorded at ranges corresponding to shadows. Thus, as the towed unit moved along, from successive pings it created a picture of the sea floor similar to that used by cartographers to show roughness of terrain, or similar to the "PPI" (plan position indicator)

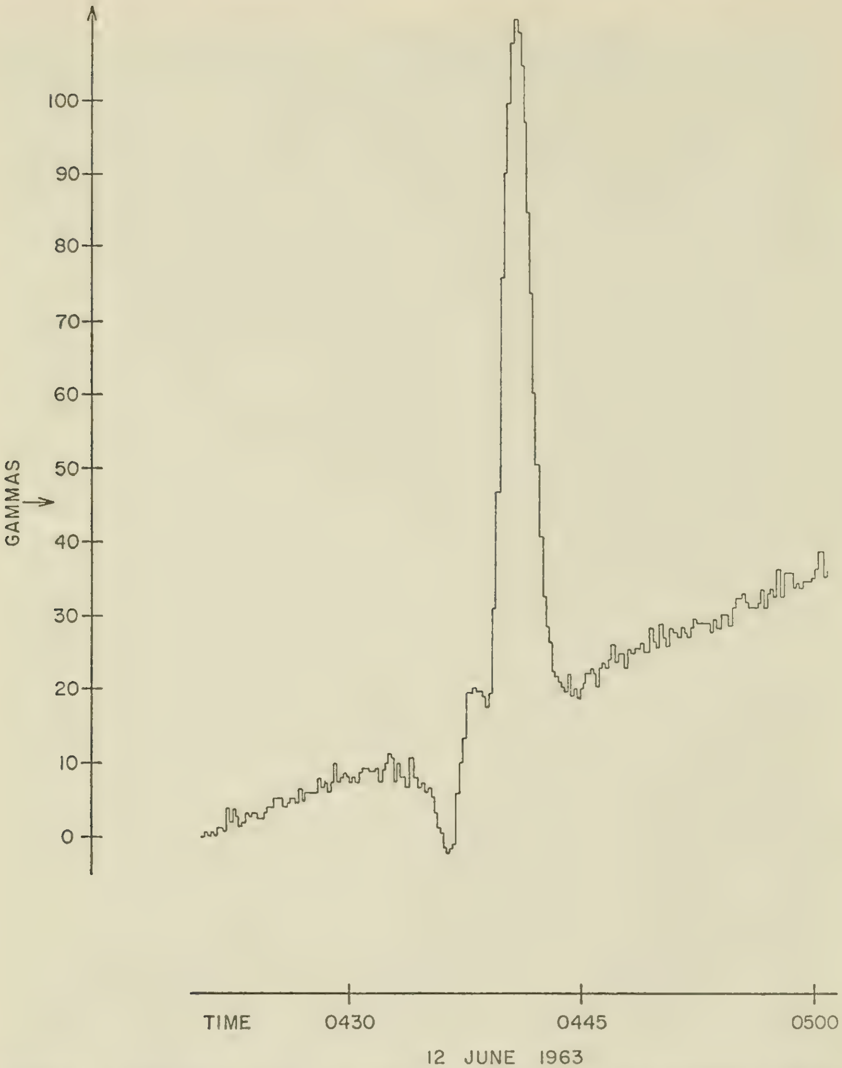


Figure 1.—Graph obtained with the deep-towed proton precession magnetometer, showing an anomaly of approximately 100 gammas in the intensity of the total magnetic field. This anomaly, first observed aboard the *Conrad*, was later confirmed by observers aboard the *Gillis* and the *Gibbs*. This single clue indicates that the hull, though badly torn, is still essentially in one piece. (Courtesy the Lamont Geological Observatory.)

display from a radar installation looking out at a flat angle over the land. Many informative pictures were obtained with this unit, but none could be positively identified with *Thresher*.

TRIESTE AIDS THE SEARCH

As additional evidence from photography, television, magnetometers, and side-looking sonar was accumulated, it became evident that the most promising region, where search should be concentrated, was

the small area directly to the east of the strip of debris charted by *Atlantis II*, *Gillis*, and *Conrad*. This was the area in which the magnetometer contacts were obtained, as well as the photographs of the larger pieces of debris. Because this area was sufficiently restricted in size to allow effective use of *Trieste*, the bathyscaphe was brought to the scene. She is one of the few craft in the world (and the only one belonging to the United States) which can operate to the depth necessary for observing the bottom in this area. Like all others (French and Japanese craft), *Trieste* lacks the cruising range and maneuverability necessary for an extensive search operation, but her observational capability makes her a useful investigative adjunct, once an area of high probability has been established. Operation of this craft is time-consuming and provides a good example, for the nonseagoing scientist, of the slow pace at which many seagoing experimental activities must be conducted. *Trieste* must be towed from port to the operating area at a speed set by the conditions of wind and sea, at best not in excess of 5 knots. She is essentially a fair-weather vehicle and is very vulnerable if caught under tow in a storm; thus, she is not taken out of port unless there is a prediction of good weather for the entire operation period.

In the present case, the tow from Boston took about 3 days. Once on station, it is necessary to transfer personnel from the towing ship to *Trieste* in small boats, and to maintain divers in the water until she has started her descent. This portion of the operation typically takes more than an hour. Once on her way, *Trieste* sinks at a rate of less than 1 meter per second, requiring some 60 minutes to reach bottom in the *Thresher* area. After *Trieste*'s arrival on the bottom (and possibly after oscillating maneuvers to free her from mud, if her descent was not checked in time), her ballast is adjusted and she can begin to cruise horizontally at speeds of ½ to 1 meter per second at an elevation of about 10 meters above the sea floor. From this position, one of the three men in the sphere (2 meters in diameter) can observe a patch of sea floor a few meters wide and 10 to 15 meters long, ahead of the vehicle. Her turning circle is about 20 meters in diameter, and thus a 180-degree turn takes about 2 minutes and no single spot on the sea floor can be kept in view during that time. When the battery supply is exhausted, after she has been at the bottom for 4 or 5 hours, ballast is released and she ascends to the surface. Once the *Trieste* is at the surface it is necessary to check out all equipment, recharge batteries, and load ballast before she can make another dive. One dive per day is her maximum capability under good weather conditions in this area.

Trieste made two series of five dives each in connection with the *Thresher* search. Because of navigational difficulties and minor malfunctions of equipment, only two out of each five dives were highly

successful. The remaining three dives per series, while useful, provided essentially negative evidence, such as evidence on where *Thresher* was *not*. During these dives, personnel of the *Trieste* were able to plot the limits of debris on the bottom, obtain photographs (pl. 2, fig. 2) of many parts of the hulk (including draft markings from the bow), and recover pieces of the debris. The debris area has been described by the *Trieste's* pilot, Lt. Comd. Donald Keach, as "resembling an automobile junk yard." Unfortunately, a magnetometer aboard the *Trieste* did not operate properly and the magnetic anomaly observed by the surface ships could not be positively associated with the debris. Radiation detectors, both total-count and pulse-height analyzers, showed the radioactivity in the area to be normal and to be attributable primarily to the potassium-40 in the sediments.

Results from the *Trieste* operations showed the microstructure of the bottom to be sufficiently complicated to make further use of surface echo sounders impractical. As a consequence, considerable effort was expended to improve deep-towed instrument packages. The Navy Research Laboratory combined their television camera unit with a proton precession magnetometer and a side-looking sonar (pls. 3 and 4). Although there was interference between the various components, nonetheless, the advantage and practicability of multiple sensors was amply demonstrated. Even with this increase in capability there remained the problem of accurate navigation with respect to the bottom, which hampered all phases of the search operation.

NEW TRACKING SYSTEM

As the difficulties in finding *Thresher* became more apparent it also became clear that a major requirement would be the ability to keep a record of the tracks of various instrument packages and of *Trieste* in their traverses across the area. Initial estimates of the positions of deep-towed instruments relative to the towing ships were made from knowledge of the ship's speed, the amount of towing wire used, and the angle of the towing wire at the ship. However, the currents in the area are not constant, either as a function of time or as a function of depth; thus, particularly at the low towing speeds which were necessary, the 3000 meters of wire allowed a considerable position uncertainty. It was known from other work that acoustic methods could be used to determine the position of the tow relative to the tending ship. Thus, the Woods Hole group on *Atlantis II* put into operation a tracking system in which a sound source on the towed package transmitted a signal picked up by three elements, two mounted (fore and aft) on the ship and the third mounted on an outrigger to provide a 15-meter athwartship separation between the receivers. With this arrangement and with knowledge of the water depth from echo sounding, it was possible to compute the approximate position

of the sound source. By the time the *Trieste* made her second series of dives, a more elaborate tracking system, assembled by the Applied Physical Laboratory of the University of Washington, had been installed on the research ship *Gillis*. In this system a short pulse signal is transmitted from the ship and answered automatically by the sound source (transponder) on the tow. Three receivers are mounted on the ship, and their outputs are fed to a computer which produces all three coordinates of the transponder relative to the ship for each pulse.

This system was used to track *Trieste* in her second series of dives and to navigate *Gillis* relative to a transponder fixed to the sea floor. Throughout the entire operation consideration had been given to the use of acoustic transponders or beacons to mark various reference points, but erratic performance and fear of overloading the area with confusing noisemakers made the Advisory Group reluctant to use them extensively.

While acoustic methods seemed appropriate for use with most instrument packages, there was also a realization on the part of some participants that even simple, after-the-fact, knowledge of the position of photographic equipment relative to the sea floor would be useful. This led to the use of "fortune cookies"—plastic sheets (40 by 55 cm.) numbered sequentially, rolled, tied with a soluble band, weighted, and dropped into the sea by one of the ships. This provided strings of spots on the sea floor which were then used for correlating different photographic sequences traversing the same area. This system also proved useful in orienting observers during bathyscaphe dives.

Following the second series of *Trieste* dives the weather began to worsen, and the decision was made to terminate the entire operation, at least for 1963. By that time the debris area had been well determined and convincing photographs and pieces of material from within the submarine had been obtained; there no longer remained any doubt that the site of the accident had been found and that any properly equipped ship could return to the debris area at will. The evidence clearly indicated that some catastrophic event had occurred as the eventual result of loss of buoyancy and control by *Thresher*. It did not appear that any direct information on the chain of events leading to the violent hull failure could be reconstructed from the debris thus far found. Some questions still remain, however, which make the area an interesting one for testing new and improved systems for sea-floor search. Specifically, the location and condition of the remains of the pressure hull and the reactor are of considerable interest, particularly in view of the variety of credible hypotheses as to their behavior that have been proposed. These range from a hypothesis of complete burial in the sediment, due to high sinking speed, to one of possible temporary surfacing of a portion, resulting

from a diesel-engine-like explosion following rapid flooding from one end.

Further activity in the search area this summer is already under way. Complete systems combining acoustic, magnetic, and photographic techniques are being used, in connection with careful sonic navigation. *Trieste* has been extensively rebuilt (this work had been started prior to the *Thresher* accident) and has returned to the scene as a far more rugged piece of seagoing machinery. Concurrently, the Navy is preparing to implement a long-term development program, based on work of special study group (the deep Submergence Systems Review Group), which will give it capability in locating, examining, and (in special instances) recovering objects on the deep sea floor. This program will include the construction and outfitting of small submarines having greater mobility, cruising range, and work capability (though not greater operating depth) than *Trieste*. Many marine scientists have long desired development of craft with the observational, instrument-planting, and recovery capabilities that these small submarines will have. It is unfortunate but true that it has taken the *Thresher* tragedy to awaken many to our lack of ability to investigate the deep sea—a lack not of basic knowledge of fruitful techniques but of experience and equipment in being. Such capabilities as we had a year ago grew directly out of our existing marine research effort. The new capabilities which are being brought into being as a result of last summer's work will help push forward our ability to make even more fruitful exploration of the depths of the sea.

Recent Events in Relativity[1]

By Milton A. Rothman

Research Physicist, Plasma Physics Laboratory, Princeton University

It may happen in some future time that a man will be able to step into a spaceship and travel to another solar system at a speed approaching that of light. If this ever occurs, certain events predicted by the theory of relativity will take place, events decidedly peculiar by present standards.

Suppose, for example, that our traveler sets out for a star 10 light-years distant, and is quickly able to attain a velocity of 90 percent that of light. It will take him about 11 years to reach his destination, and if he then turns around and comes back at the same speed, 22 years will have elapsed on earth by the time he makes his landing.

To the voyager, matters appear somewhat different. Once he reaches a constant velocity, he feels no sense of motion. However, he sees the earth receding and the destination approaching at a speed 90 percent that of light. Owing to the contraction of length predicted by relativity, he finds that the distance to be traveled is only 4.35 light-years, rather than 10 light-years. Therefore, he finds it takes him only 4.85 years to go, and an equal time to return, or a total round trip time of 9.70 years.

As a result, a person who has remained on earth finds himself aged 22 years, while the person who went on the trip is aged 9.7 years. Time has been going more slowly on the spaceship than on the earth. This is in agreement with rule 4 of table 2, which gives some of the conclusions drawn from the Special Theory of Relativity.

On the other hand, we might raise an objection to this conclusion. While a clock in motion appears to be going more slowly than a clock which is at rest with respect to the observer, the *direction* of motion does not enter into the equation. If motion is completely relative, then as far as the man in the ship is concerned, it is the earth which is

[1] Reprinted by permission from *Foote Prints,* vol. 33, No. 1, pp. 15–24, copyright 1963 by the Foote Mineral Company, Exton, Pa.

moving. Therefore the man in the ship should find that the clock on the earth is going more slowly than his clock.

The traveler feels that he should be the older one at the end of the trip—not the one who stayed home!

This famous "clock paradox" has been well-known for many years, and has been discussed thoroughly by a great many writers. The consensus has been that indeed the traveling man would come back to earth younger than the stay-at-home individual. In spite of this, there has been a vocal minority which has maintained that there would be no difference in age between the two people (Dingle, 1956, 1957).

Until very recently there was no experimental evidence bearing upon this paradox one way or the other. After all, it has proven difficult enough to get an observer out in space without getting him up to relativistic velocities—that is, velocities great enough to observe these small effects. It requires a speed of 42,000 kilometers per second to produce a 1-percent change in the length, mass, or time rate of a body. With ordinary laboratory or rocket-type velocities, the effects are exceedingly small.

However, during the past 2 years a new laboratory tool (the Mössbauer effect) has made possible experiments of such precision that previously they were not considered feasible. As a result of this, interest in experimental proof of the Principle of Relativity is now at a higher level of activity than ever, despite the fact that a great many facets of the theory have already been proven in the 55 years since Einstein first proposed it.

Since relativity is the foundation of modern physics, any experiments which help establish its validity are considered very fundamental and important. The newly invented techniques illuminate certain aspects of the theory which have been inaccessible up to now.

THE PRINCIPLE OF EQUIVALENCE

The Special Theory of Relativity is based upon the two assumptions listed in table 1. While the Special Theory (published by Einstein in 1905) deals with observers moving at constant velocity, the later

TABLE 1.—*Basic Assumptions of the Special Theory of Relativity*

1. The velocity of light in free space is always a constant, regardless of the motion of source or observer.

2. The laws of nature are always the same to any observer moving with constant velocity, regardless of this velocity.

The Principle of Equivalence: A body in a gravitational field behaves exactly the same as it would if it were subjected to an equivalent acceleration, without the presence of the gravitational field.

and more elaborate General Theory (1915) deals with accelerated systems. In an intermediate paper of 1911, Einstein discussed the Principle of Equivalence (table 1), which has been the subject of some of the recent experiments.

This principle, in effect, says that if we do an experiment on the surface of the earth, under 1 g. of gravitational acceleration, then we should get exactly the same result if we do the experiment out in space, in a ship undergoing 1 g. of rocket acceleration. In fact, we see here that the terminology of the astronaut explicitly recognizes the Principle of Equivalence, for 1 g. of acceleration always means the same thing, whether it is caused by gravity or rocket thrust.

What this implies is a very basic assumption: Gravitational mass (the mass which determines the force of gravity) is exactly the same as inertial mass (the mass which determines the acceleration resulting from an applied force).

If this were not true, then bodies with different masses would fall at different rates. It has not always been obvious to people that different masses do fall at the same rate. Since the time of Galileo we have believed this assumption to be true. Nevertheless, our experiments are only approximations, and there is always the chance that an experiment giving another decimal place of accuracy might discover small differences between gravitational and inertial mass. Because of this, we are always on the alert for new and novel experiments which tend to settle the question more definitely.

The predictions of the Special Theory, listed in table 2, have been verified by numerous experiments during the past 50 years. However, the Principle of Equivalence has not been so fortunate, since the effects which it predicts are so minute that until very recently laboratory experiments of the required precision have been out of the question.

One effect which the Principle of Equivalence predicts is the "gravitational red shift." If a source of light emits radiation which travels from a region of low gravitational potential to a region of high gravitational potential—that is, if the light is traveling *up*, then the

TABLE 2.—*Results of the Special Theory of Relativity*

1. A body which is moving relative to an observer appears to be shortened in the direction of motion.

2. The mass of this moving body is greater than when it is at rest. This increase of mass is directly related to the kinetic energy of the moving body.

3. The total mass of a body is related to its total energy according to the expression: $E=mc^2$.

4. A clock which is moving relative to an observer runs more slowly than a clock at rest.

5. The maximum velocity for the transmission of any signal is the speed of light.

frequency of this radiation is decreased. The wavelength is shifted toward the red.

Astronomers have sought to observe this in the light coming from very heavy stars. If we look at this light by means of a spectroscope, and compare the wavelength of a particular spectral line with the same line from a terrestrial source, the line from the star should be shifted toward the red. This is a very small shift, and is superimposed upon the normal Doppler shift due to the motion of the star away from the earth, so that the measurement is very difficult to make.

The same sort of shift should be observed if we use a source of light at the surface of the earth, while the observer or detector is stationed at some height above the surface of the earth (fig. 1). In this case, the amount of shift would be very small indeed.

There are a number of ways of "explaining" how this comes about, all of which are ultimately equivalent in terms of the theory of relativity. One way of understanding the reason for the gravitational red shift is to consider that the light emitted from the source is in

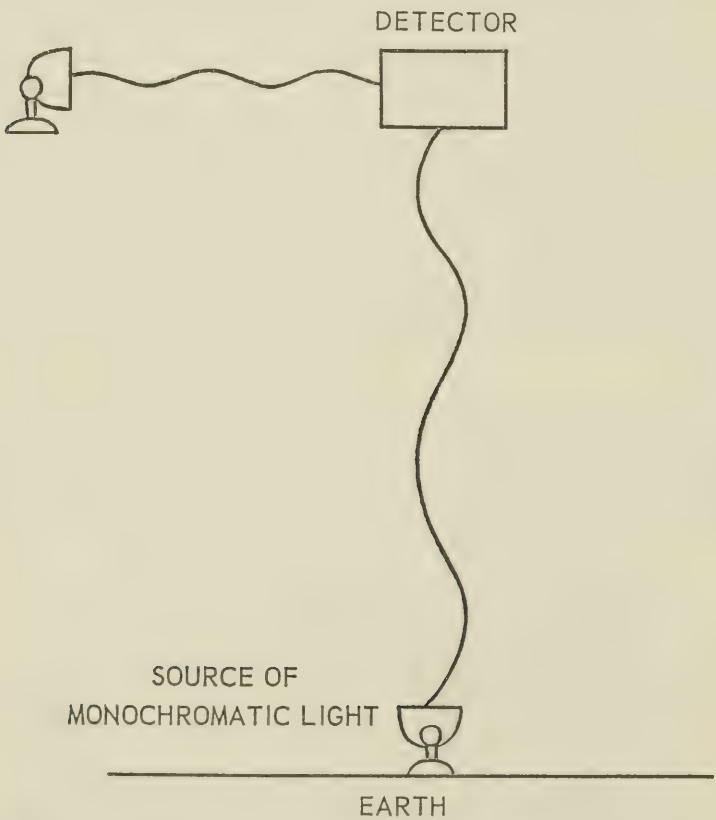


FIGURE 1.—Light traveling up from the surface of the earth has a longer wavelength than light from the same source traveling parallel to the earth's surface.

the form of photons. Each photon has a certain energy which is proportional to the frequency of the radiation. Associated with this energy is a definite mass. When the photon rises from the surface of the earth, it must do work against the gravitational field. It is "pulled back" by the force of gravity. Therefore, the photon loses kinetic energy. Since its velocity must remain a constant, this loss of energy is observed as a decrease in the quantum energy—in other words, a decrease in the frequency.

Conversely, a photon falling toward the earth must acquire an increased frequency.

An alternative way of describing the same situation is offered by the Principle of Equivalence. We imagine the source of radiation and the observer to be located in a spaceship undergoing 1 g. of acceleration (fig. 2). The source and observer are always the same

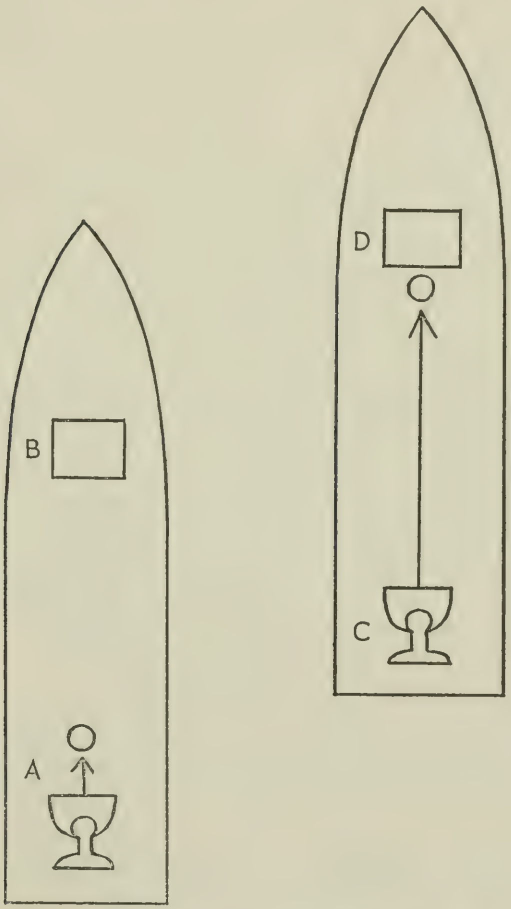


Figure 2.—Light leaving the source A heads for the observer B. By the time the light reaches the observer, the latter is at D, and is traveling faster than it was when the light left the source.

distance apart—they are at rest with respect to each other. A photon emitted by the source at A travels toward the observer at B. However, by the time this photon reaches the observer, the latter has reached the point D. In addition, the observer is now traveling faster than he was at point B, because he has been under constant acceleration.

In other words, although the source and observer always remain the same distance apart, the acceleration produces an effect as if the observer were always running away from the source. If we calculate the additional velocity acquired by the observer during the time it takes the photon to reach it, we can then calculate the Doppler shift resulting from this velocity. This turns out to be exactly the same as the shift which is calculated on the principle that the photon is rising against the acceleration of gravity.

The statement is sometimes made that the gravitational red shift is observed when the source of light is in a stronger gravitational field than is the observer. However, this is incorrect, since the calculation outlined above shows that the shift can be observed even when source and observer are in a uniform field. The only thing that matters is that the observer must be higher than the source. In other words, it is the difference of potential that enters into the calculation. If the observer is lower than the source, the result will be a blue shift.

Measurements of the gravitational frequency shift within the confines of a laboratory were formerly unheard of, because there was no way of measuring the tiny amount of shift produced by the earth's gravitational field. With the advent of satellites, proposals were made to send up very precise radio-frequency oscillators, whose signals would be compared with those of an identical oscillator down on the ground. Since the amount of shift depends on the difference in altitude between transmitter and receiver, it was calculated that a measurable effect would be obtained.

However, before this could be done, a development in a totally unexpected direction made these satellite experiments obsolete before they were even undertaken. This new development came from the field of nuclear physics, and it came from a rather obscure corner of a specialty known as low-energy nuclear spectroscopy.

THE MÖSSBAUER EFFECT

The story illustrates quite beautifully the strongest argument in favor of basic research: You never know when a piece of research will turn out to have important consequences in an unpredictable application.

For several years a number of nuclear physicists have been using the phenomenon of nuclear resonance fluorescence to measure properties of the excited states of various nuclei. This is based upon the idea

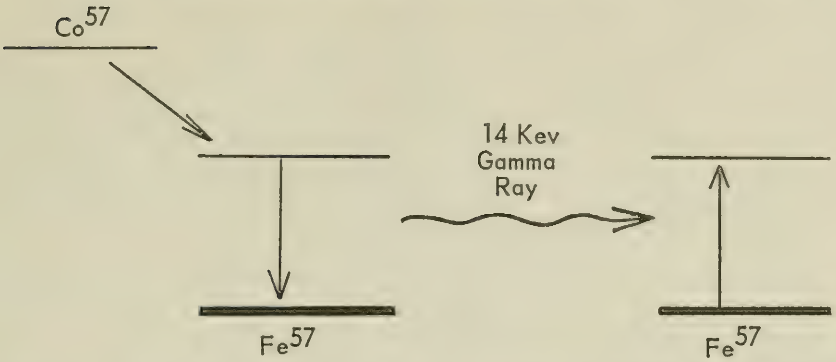


FIGURE 3.—Radioactive cobalt-57 decays by beta emission to an excited state of iron-57, which quickly emits a 14-kev gamma ray. If this gamma ray photon encounters another nucleus of iron-57, it may be absorbed.

that when a nucleus has been raised to an excited state, it decays to the normal ground state by emitting a gamma ray of a definite frequency. If this gamma ray now encounters another nucleus of the same kind as the first, this second nucleus may now be raised to its excited state by absorbing the energy of the gamma ray (fig. 3).

This is a resonance effect. If the gamma ray differs in frequency by as little as one part in 10^{12} of the resonance frequency, the absorption will be greatly reduced—the amount of reduction depends upon the "width," or energy spread, of the excited level. Theoretically, at least, the absorption can be measured by counting the gamma rays from an appropriate radioactive source first with and then without the proper absorber between the source and counter.

Unfortunately, when a nucleus emits a gamma ray, some of the energy of the excited state goes into recoil motion of the nucleus. This means that the gamma ray frequency is reduced considerably, so that when it hits a nucleus which might be receptive to it, it is far-off resonance, and there is no absorption at all. In the past, people have managed to compensate for this recoil motion by heating the source or by whirling it around in a centrifuge.

In 1958, R. L. Mössbauer, a young German physicist, discovered that in a few favorable cases one could obtain gamma rays with practically no recoil at all (Mössbauer, 1958; Benedetti, 1960). There are a few radioactive elements which emit rather low energy gamma rays and which are so strongly bound in their crystal lattice that the recoil energy is taken up by the crystal as a whole rather than by the individual radiating nucleus.

Immediately, a number of physicists realized that the Mössbauer effect provided a source of radiation of unparalleled precision, as far as the energy (or frequency) of the radiation was concerned. The

most commonly used isotope is cobalt-57, which decays by the emission of beta rays to iron-57, with a half-life of 280 days.

Following the beta emission, the iron-57 nucleus is in an excited state which lasts for about a tenth of a microsecond, a reasonably long time as nuclear lifetimes go. It now emits a gamma ray of about 14 kilo-electron-volt energy, which corresponds to a frequency of 3×10^{18} oscillations per second. This gamma ray may be visualized as a wave packet containing about 10^{12} waves altogether.

If this packet encounters another iron nucleus likewise bound in a crystal lattice, it is able to raise the nucleus up to its 14 kev. excited state, and is absorbed in the process. The nucleus behaves as a very delicate frequency-measuring device. If the frequency of the incoming wave varies by only one part in 10^{12}, the probability of absorption will be reduced by a large factor.

Thus we have a wave whose frequency is very sharply defined, and we also have a measuring device which is equally sensitive to changes in frequency.

So sensitive is this system that if the source is moving only a few millimeters per second with respect to the absorber, the resonance is wiped out, due to the Doppler shift in the emitted frequency. The standard method of doing a Mössbauer effect experiment is to have a radioactive source mounted on some device (such as a lathe carriage) which can move it at a known speed toward or away from a scintillation counter which counts the number of photons transmitted through an absorber (fig. 4). If the source is iron-57, the absorber is usually of iron enriched in the isotope iron-57. By plotting the number of photons counted in a given time at various source velocities, the resonance curve shown in figure 5 may be obtained.

The measurement of this type of resonance curve is the basis for all of the recent experiments which have been performed to test the theory of relativity.

The theory of the Doppler shift informs us that the frequency of the emitted radiation is increased when the source moves toward the absorber, and is decreased when the source moves away from the

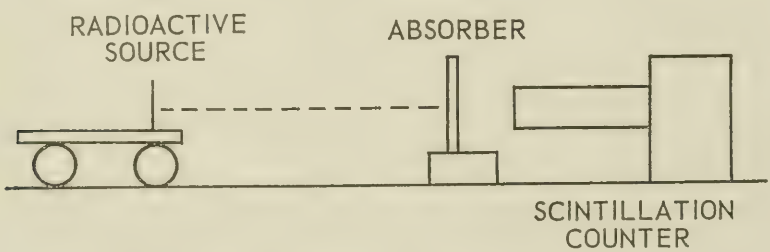


FIGURE 4.—The basic apparatus for a Mössbauer effect experiment.

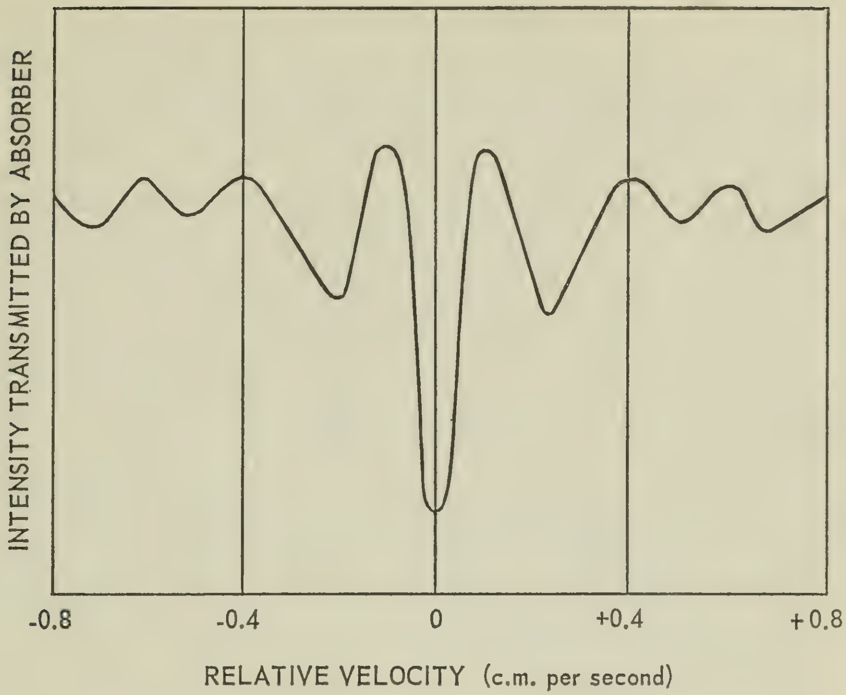


FIGURE 5.—Typical resonance curve obtained by the apparatus of figure 4.

absorber. (This refers to those photons which are moving toward the absorber.)

In addition, there is another, much smaller, reduction of frequency which always takes place, no matter what the direction of motion. This is an effect of relativity, and has been of the greatest interest in the recent experiments.

When the source (or the observer) is moving at right angles to the motion of the radiation, only the small effect of relativity is observed. This reduction of frequency—the "transverse Doppler shift"—arises from the slowing down of the atomic clocks in the moving source. This is the relativistic time dilatation, and the amount of slowing down depends only upon the magnitude of the relative velocity between the source of radiation and the observer.

The transverse Doppler effect was recently observed in an experiment performed at Harwell, England, using the Mössbauer effect as a tool (Hay et al., 1960). The radioactive source was placed at the center of a rotating wheel, while the absorber was at the edge. The scintillation counter was at rest outside the periphery of the wheel. In this arrangement the absorber is always moving at right angles to the photons, and so any shift in frequency is a result of the transverse Doppler effect, and is therefore a manifestation of the time dilatation.

WEIGHING THE PHOTON

Perhaps the most extensive and completely worked-out test of relativity performed with the Mössbauer effect has been that of R. V. Pound and G. A. Rebka, at Harvard, begun early in 1960, and still in progress.

The initial purpose of this experiment was to check the gravitational red shift, and in the course of doing this it almost incidentally cast a great deal of light on the problem of the clock paradox.

Pound's experiment measured the change in the resonance between an iron-57 source and an iron absorber (enriched in iron-57) differing in height by a distance of 74 feet. The apparatus was set up in a tower at Harvard University which, fortunately, had been built many years previously for an entirely different purpose.

When the source is at the bottom, the frequency of the radiation is shifted to the lower side of the resonance point, because the photons must lose energy in rising against gravity, as described previously. This, in effect, measures the "weight" of the photons. When the source is at the top, on the other hand, the absorber "sees" that the frequency

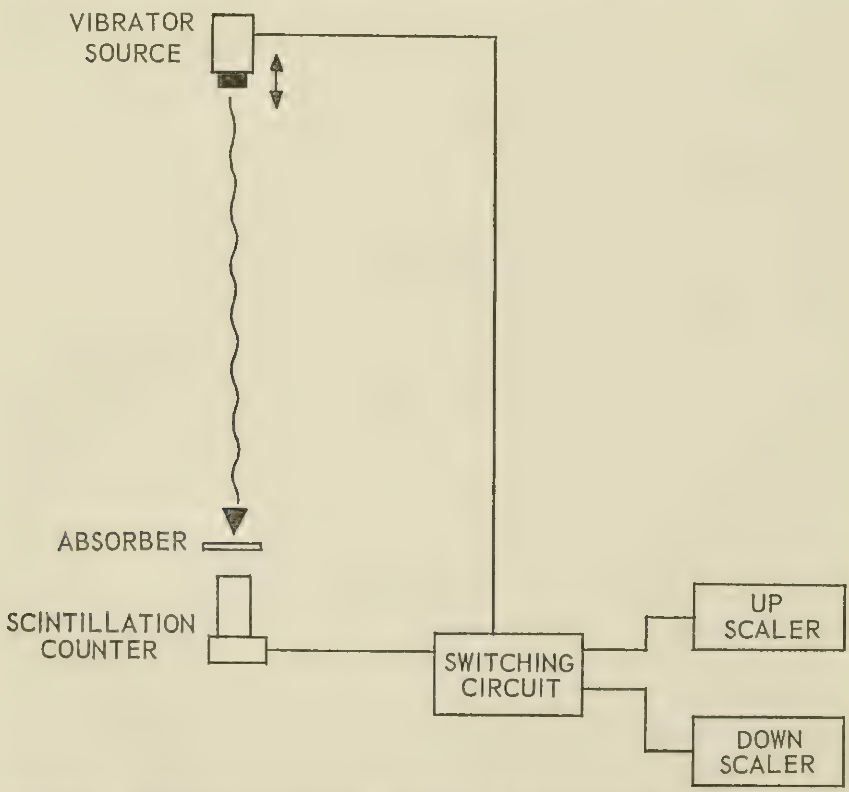


FIGURE 6.—Experimental arrangement for measuring the gravitational red shift by means of the Mössbauer effect.

of the descending photons has shifted toward the high side of the resonance frequency.

The actual percentage shift in frequency measured in this experiment is rather small, amounting to about 5 parts in 10^{15}. If you were performing this experiment with a 100 megacycle radio-frequency oscillator, you would have to detect a change of five cycles out of about 4 months' operation of the oscillator to obtain the same sensitivity. The method for measuring this small change by means of the Mössbauer effect is as follows (fig. 6):

The radioactive source is mounted on a vibrator so that it moves rapidly up and down—toward and away from the absorber. The scintillation counter is connected to scalers through electronic switches so that one scaler is counting while the source is moving towards the absorber, and the other scaler is counting while the source is moving away from the absorber.

The Doppler shift due to this motion changes the frequency of the gamma rays to points above and below the center of the absorption resonance (fig. 7). If both source and absorber were at the same height, the scalers would be counting at points A and B on the curve. However, if the source is higher than the absorber, the photons are shifted to slightly higher frequencies when they reach the absorber,

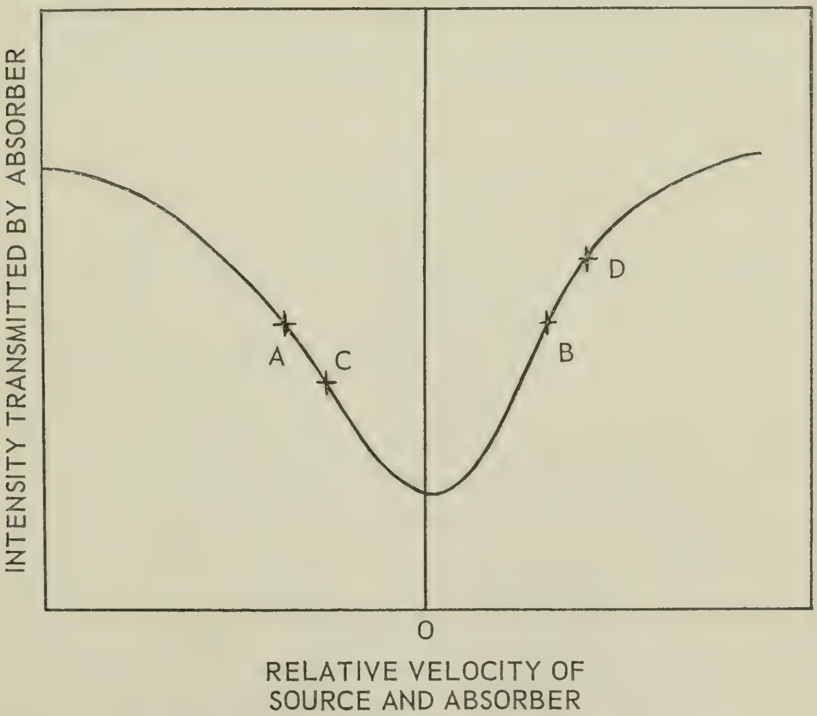


FIGURE 7.—Effect of gravitational shift upon resonance curve.

and so the counts are measured actually at points C and D on the curve. The difference in counting rates between the two scalers measures the change in frequency due to the gravitational effect.

Because of the 74-foot distance between the source and detectors, the counting rates are rather low, and it takes many hours to acquire sufficient counts to give good statistics. In the course of the experiment it was noticed that there was a slow drift in the relative counting rates of the two scalers—a drift large enough to wipe out the effect being sought. The drift was somewhat periodic—with a period of about 2 days.

After a good deal of soul-searching and examination into possible causes for this drift, it was finally realized that this error was a result of the small temperature difference between the source and absorber. It requires a difference of only 1° C. to produce a frequency shift as large as the one being looked for.

The temperature correction turns out to be directly related to the relativistic Doppler shift mentioned previously. The atoms of the radioactive source are vibrating in their crystal lattice with a mean-square velocity proportional to the temperature, and the relativistic Doppler shift depends upon just this velocity. Utilizing this as a basis, Pound calculated the amount of correction to apply in order to eliminate the temperature effect.

When this correction was used, it was found that the remaining frequency shift agreed very well with that calculated from the theory of relativity, using the 74-foot difference in height between the source and absorber.

In this way the gravitational "red shift" was verified.

THE CLOCK PARADOX

Following publication of this experiment, it was noticed by C. W. Sherwin, of the University of Illinois, that the clock paradox plays a role in this situation (Sherwin, 1960).

We recall that the relativistic Doppler shift is associated with the time dilatation of the moving source. In the present experiment, the source of radiation is an atomic nucleus which is vibrating back and forth in a crystal lattice with a mean-square velocity proportional to the temperature of the material. The emitting nucleus actually goes back and forth many times during the time that the wave packet is being emitted.

This, we see, is very much like the clock paradox situation described at the beginning of this article. Instead of a spaceship going away and coming back, we have a radioactive nucleus going away and coming back many times. The radiation passing between the emitter and absorber is a means of continually comparing the clocks located on the

"spaceship" and "earth." The clock, in this case, is the resonant frequency of the nucleus in the act of emitting or absorbing the radiation.

The effect actually observed is this: The nucleus traveling with the highest average velocity (at the highest temperature) has the lowest resonance frequency. In other words, its clock runs at the slowest rate, as seen by the observer in the laboratory, who considers himself motionless.

In terms of our original paradox, the man who goes off in the spaceship will always return to find himself younger than the man who stayed at home. His time has been passing at a lower rate.

What is it that makes the difference between the clock on the ship and the clock on earth? What is it that makes the situation unsymmetrical?

It is simply the fact that in order for the spaceship to go away and come back, it must undergo acceleration at least once during the trip. The clock on earth has been moving at a constant velocity in the meantime. It is this difference which allows us to put a label on the one who is going to emerge with the slower clock at the end of the voyage.

The experiment of Pound and Rebka has verified that the magnitude of this effect—the amount by which the clock slows down—depends only upon the mean-square velocity of the moving bodies. It does not depend upon the magnitude of the acceleration, or upon the amount of time between accelerations. In this experiment both the source and absorber nuclei are moving, both clocks are slowed down relative to the laboratory observer, and therefore the difference between the two clock rates depends upon the difference in temperature between source and absorber.

This experiment is not the first time that the time dilatation effect has been observed in the laboratory. The relativistic Doppler shift was measured by H. E. Ives in 1938 by observing the light emitted by rapidly moving hydrogen atoms. However, this new experiment marks the first time that the effect has been observed using the radiation from a source which is moving back and forth, thus duplicating the situation of the clock paradox.

CONCERNING THE SHAPE OF MOVING OBJECTS

For many years we have agreed that an object moving at a high velocity will appear to be shortened in the direction of motion. This idea originated even prior to Einstein. It is, in fact, called the Lorentz-Fitzgerald contraction in honor of the prerelativistic scientists who conceived it in order to explain away the observation that light always has the same velocity regardless of the motion of the observer.

As a result of this, writers of science fiction have spoken of long, thin spaceships appearing to be short and squat when in motion, while the passing stars are turned into ellipsoids.

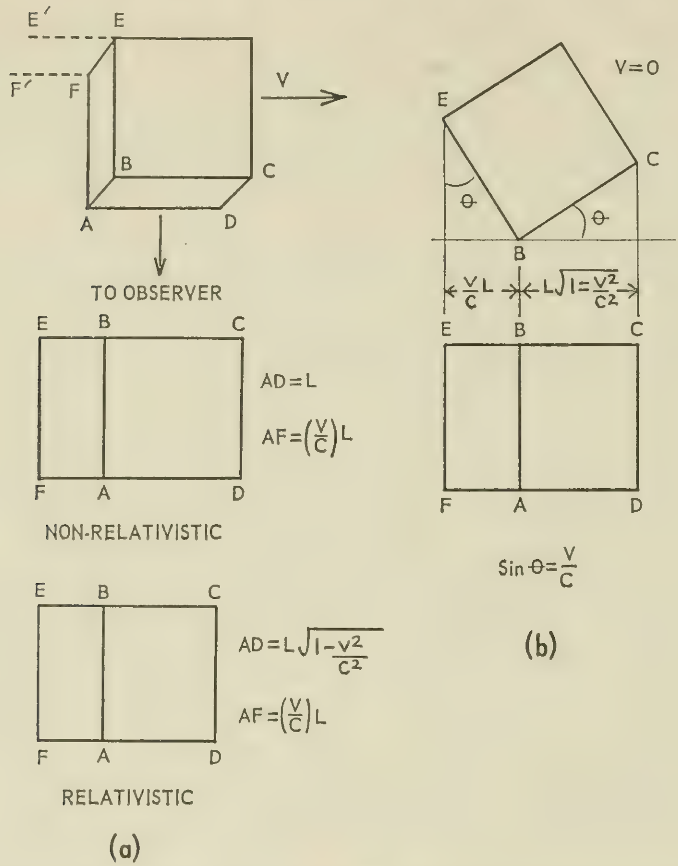


FIGURE 8.—(a) Appearance of moving cube. (b) Appearance of rotated cube.

It now appears that we have all been wrong.

Fortunately, the basic ideas have not been wrong—only the interpretation of what we would actually observe have been mistaken. The error was recently pointed out by J. Terrell (1959), and expanded on by V. F. Weisskopf (1960). It is one of those embarrassing things which appears obvious after it is pointed out to you.

Suppose we consider a cube which is moving at right angles to the observer's line of sight (fig. 8). The observer takes an instantaneous photograph of the cube, so what he records is the position of those light rays which reach the photographic plate at one instant of time.

Our first impulse is to say that we would simply see one side of the cube—the square *ABCD*. However, we must keep in mind the fact that the points *E* and *F* are farther away from the photographic plate than points *A* and *B*. Therefore light from *B* which leaves the cube at a certain instant will reach the plate at the same time as light from *E* which left the cube L/C seconds earlier. But during that time the

cube moved a distance Lv/c. Therefore it is really the light from E' which reaches the plate simultaneously with light from B.

Thus we would expect to see a picture like the one labeled "Non-Relativistic," where we find a square $ABCD$, followed by the projection of the rear end of the cube, $ABEF$. Without relativity, we expect to see a distorted, elongated picture of the moving cube.

How does relativity change the situation? Relativity says that all lengths are shortened in the direction of motion by the factor $\sqrt{1-v^2/c^2}$. The other lengths, at right angles to the direction of motion, are not changed. Therefore, under the relativistic interpretation, we would see the shortened square $ABCD$, followed by the rear end of the cube, $ABEF$, as shown in the diagram labeled "Relativistic."

What makes this interesting is illustrated in figure 8*b*. If we take the same cube, motionless, but simply rotated through an angle Θ, whose sine is v/c, its picture will be exactly the same as the one obtained from the moving, relativistic, cube.

In other words, a person looking at a cube moving rapidly will see that it appears to be rotated through the angle Θ, but that it otherwise appears normal. Previously, the relativistic interpretation would have said that the cube appeared shortened—now we say that it appears rotated.

When this argument is applied to a sphere, such as a star or planet, we conclude that the sphere remains spherical in shape, but appears to be rotated. If you were moving fast enough you could see part way around the opposite side of the sphere.

Professor Weisskopf, in his paper, goes into the details of how a moving object changes its appearance as it comes towards us, passes by, and then recedes. In brief: We first see the front face of the object, strongly Doppler shifted to high frequencies. When the angle of vision reaches a certain value, the color shifts toward lower frequencies, the intensity of the light drops, and the object seems to turn. Soon the object has turned all around and we are looking at its trailing face. As Weisskopf says, "It is the picture expected when the object is receding. However, it appears already when the object is moving toward us."

This description, of course, applies only to objects which are moving very nearly at the speed of light.

As stated originally, none of this invalidates the basic findings of the theory of relativity. It merely emphasizes, as many have found to their chagrin, that we must always be very careful in interpreting the results of the theory.

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The Edge of Science[1]

By Sanborn C. Brown

Associate Dean, Graduate School, Massachusetts Institute of Technology

It is very seldom in the life of a scientist that a whole new vista of knowledge opens up, vast and challenging before him. But this has really occurred in what has come to be called plasma physics.

In physics a plasma is defined as a neutral collection of electrons and positive ions (atoms that have been stripped of their electrons) which move around in random thermal motion. We have discovered that this is the most common form in which matter is found in the universe. If you go out into the far reaches of so-called empty space, or to the stars or the solar system, or almost anywhere in the galaxy except our peculiarly cold bit of dust which we call the Earth, you will find matter in this ionized state, the plasma state. Nearly all of the matter in the universe is in this state, and yet it is only within the past 10 years or so it has been recognized as a common state of matter. The whole subject of what we call plasma physics has excited a great fraction of the scientific community.

To bring order into a fairly chaotic collection of phenomena, I refer you to a plot in which the nature of matter is defined in terms of two variables: the density of electrons per cubic meter and the temperature at which these electrons are to be found. The diagram shows the various areas covered by plasma physics.

To start our discussion we begin in the lower left corner of this diagram. If we get to very cold electrons and to very transparent matter, we are in what is called interstellar space, including any nebulae we find in a study of the sky. It has not been long since all our information about the interstellar space came from visual telescopes. Collections of charged particles such as electrons and hydrogen nuclei, which are dancing around in space, but which are still held together by their mutual gravitational attraction, are not necessarily visible optically but may be visible by radio telescopes. We call these collec-

[1] This article is based on Professor Brown's remarks at the Alumni Symposium on "Engineering, Science, and Education for Tomorrow," held in Newark, N.J., April 18, 1964, and is reprinted by permission from the *Technology Review*, vol. 66, No. 9, July 1964.

tions "stars." Many of you are aware of the tremendous amount of work which is going on all over the world in studying the nature of the electrical signals which we get from these interstellar spaces.

Interplanetary space, that is, space within our own solar system, which on the average happens to be kept warmer because we have the hot sun in our vicinity, reaches temperatures of around 10,000 degrees K. In interplanetary space the number of particles per cubic meter, except when we actually get to the surface of a planet, is fairly small, between a million or perhaps 10 million particles in each cubic meter. This is fairly transparent space. The interplanetary plasmas are of extreme importance to modern science because it is through this medium that we must travel if we are to go out any distance from the surface of the earth into interplanetary space, where we have already sent a fair number of probes. The physicists and engineers who are involved in space research are studying the mechanisms and the interactions of the plasma state in these interplanetary regions.

Perhaps the one astronomical area that has been studied most is the Earth. Around it there is a charged blanket resulting from the fact that the atmosphere attached to the earth is being bombarded by solar radiation and the solar radiation produces a plasma from the neutral gases which make the earth habitable. This layer is called the ionosphere and always insulates us from the outside space. This plasma blanket around the earth has been well known for a long time. It is relatively cold, 1,000–10,000 degrees K, and the electron density can get fairly high, up to about 10^{10}–10^{11} electrons per cubic meter. There are some very interesting and important phenomena which occur as a result of this ionospheric blanket. Well known to radio engineers is the fact that you can bounce radio waves off the ionosphere. The interaction of electromagnetic radio waves with the ionosphere has been a major study for many years by both electrical engineers and physicists.

Recently the newspapers have been full of another phenomenon which was predicted theoretically long ago but actually found experimentally only a few years ago when we started sending up rockets and high-altitude balloons. This has been called the "Van Allen belts." These belts are areas of plasma concentration which have been caught in the inhomogeneous magnetic field around the earth. If you put a moving electron in a magnetic field, it has a tendency to go around in a circle, the diameter of which is inversely proportional to the magnetic field. If a charged particle is high above the earth somewhere near the equator, where the earth's magnetic field is not very strong, it goes around slowly in a big circle, but as it gets closer to the pole, where the strength of the magnetic field is greater, it must move in smaller and smaller circles. In shortening the radius of the

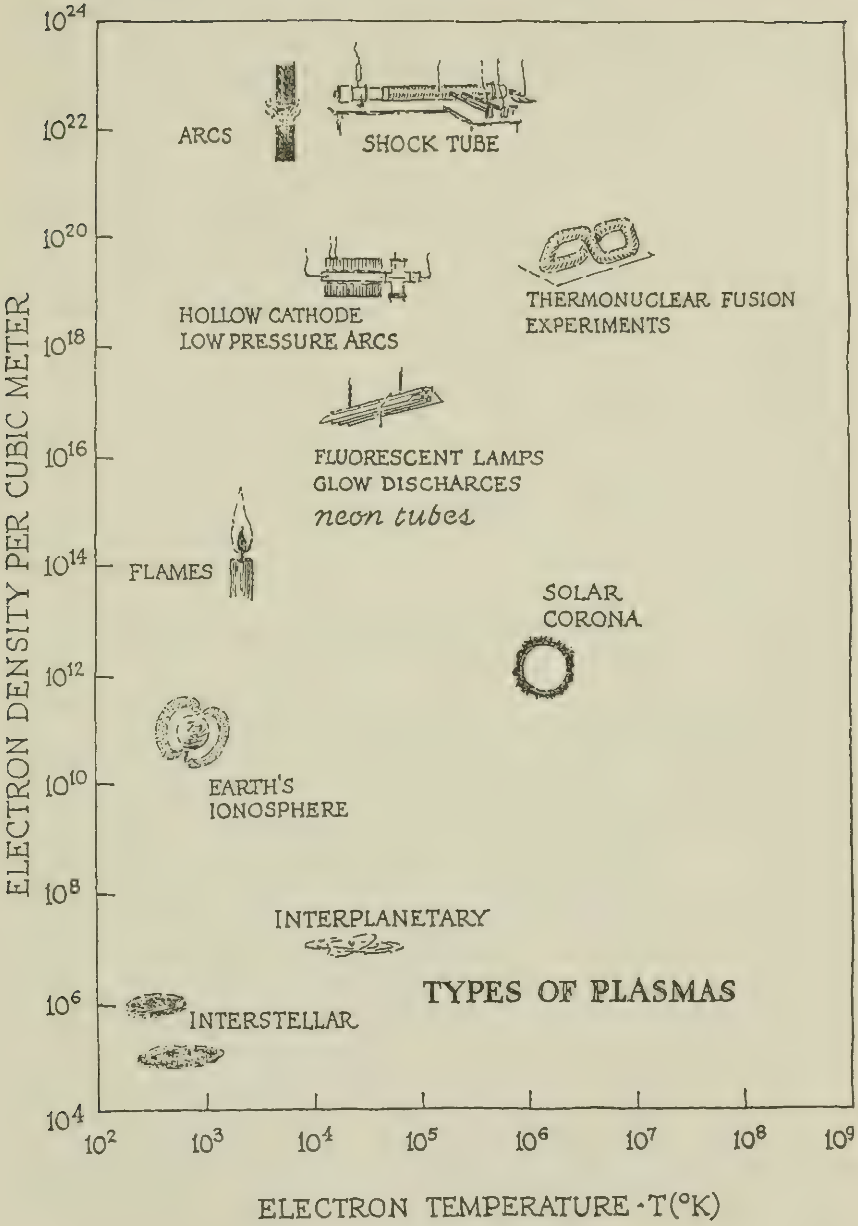
ARCS
SHOCK TUBE
HOLLOW CATHODE
LOW PRESSURE ARCS
THERMONUCLEAR FUSION
EXPERIMENTS
FLUORESCENT LAMPS
GLOW DISCHARGES
neon tubes
FLAMES
SOLAR
CORONA
EARTH'S
IONOSPHERE
INTERPLANETARY
TYPES OF PLASMAS
INTERSTELLAR
ELECTRON DENSITY PER CUBIC METER
ELECTRON TEMPERATURE - T(°K)
10^{24}
10^{22}
10^{20}
10^{18}
10^{16}
10^{14}
10^{12}
10^{10}
10^{8}
10^{6}
10^{4}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}
10^{8}
10^{9}

FIGURE 1

circle, a radial force is applied, and in conserving its angular momentum the particle speeds up so that it not only moves in tighter spirals but goes around the tighter spirals more rapidly. In the Van Allen belts, the plasma particles are caught in a gigantic "magnetic mirror." As these ions and electrons approach the poles, they are wound in tighter spirals, but as they rotate faster in smaller circles they conserve energy by moving more slowly toward the poles. In fact, they actually slow down and stop, and are then reflected by the mirror into reversing their directions. They go back and forth, caught in the Van Allen belts. The mirror effect is not perfect, and the charged particles leaking out the ends of the Van Allen belts cause the northern lights, or the aurora borealis. This electrical discharge is the visible indication of the ionosphere, or the charged plasma, escaping out the ends of the Van Allen belts.

Our very existence on earth depends upon our greatest plasma source, the sun. Its energy comes from the process we call thermonuclear fusion. Two heavy hydrogen nuclei are fused in such a way that helium is formed. There is energy left over which keeps the process going and incidentally keeps us warm. The whole process of the operation of the sun is a nuclear reaction occuring in the plasma of the sun itself.

There are some other things on the diagram that show how universal the plasma state is. Perhaps one of the earliest plasmas studied as an easy way of producing a neutral collection of electrons and ions was a flame. A flame even from a candle is not very hot, maybe 1,000 degrees K, but it is extremely dense because it occurs at atmospheric pressure. Chemical flames themselves are not usually studied, but many varieties of chemical or electric "torches" produce plasmas which are not only laboratory tools for increasing our understanding of the plasma state but are technically important tools for such varied operations as welding or chemical synthesis. Also, for example, meteors burn up when they come into the atmosphere and are reduced to the plasma state. Much of our information about meteoric physics and chemistry comes from studies of the behavior of the plasma state.

If you go to a plasma a little hotter than a flame, and a little denser, you come to the most common everyday form of plasma, a gas discharge tube of some sort, a neon sign or a fluorescent light. Most of the original studies of the plasma state were done in what was called a "glow discharge" because this was a readily available way of producing a plasma to study in the laboratory. A great deal of the information we are now gaining about the ionosphere, the sun, and interplanetary and interstellar space comes from studies made in the laboratory with a glow discharge. Practically, there are many applications of a glow discharge, particularly in the field of control and gas tubes of various sorts. Glow discharge studies not only explore

the theory of the plasma state but have led to engineering applications which have been very numerous indeed.

If we continue to pour more and more energy into an ordinary glow discharge, it turns into what we call an "arc." In an arc, the electron density can rise to 10^8 times the charge density that is found in the sun at perhaps one-thousandth of the temperature. These kinds of arc studies in the laboratory provide us with powerful tools for studying the behavior of the plasma of the sun. Incidentally, at this kind of temperature and pressure a great deal of work is now being done to produce what are called "ion jet" engines. Ion engines may well be the kind of engine that will move spaceships through the interplanetary space for long sustained flight after chemical rockets have achieved the high initial force necessary to escape the earth's gravitional field. Plasma jet engines are capable of providing a driving force over the thousand years you need to reach out into interstellar space. Obviously a great deal of practical engineering must be done before this method of ion propulsion is perfected.

The high-pressure arcs are the densest form of plasma that we know. Here, all the material that is in the arc is ionized; everything is in the charged state. Here the theoretical studies are the most characteristic of a plasma because the plasma is pure, undiluted by un-ionized gas. Here also some very practical devices are being worked on, particularly the "magnetohydrodynamic energy converter." In a conventional turbine, gas energy is converted into the kinetic energy of a moving conductor which then generates the electricity by cutting lines of magnetic flux, but if a gas conductor, a moving plasma, is used, the intermediate step is completely eliminated. The plasma moving in a magnetic field produces a flowing current which will allow us to produce generators without any moving parts. There are plans for building very large generating stations by this scheme in which the plasma is produced either by nuclear power, fission heat, or from a chemical reaction.

Making very dense plasmas and going a little farther up into the temperature region of 100,000 degrees K, we find the "shock tube" as a plasma production device. When a mechanical shock wave is driven down a tube faster than the velocity of sound, the shock wave acts as a piston. Just as with a bicycle pump, you get heat because the piston is pushing against the gas and doing work on it, so in the shock tube you can produce very high temperatures. Some of the highest temperatures we have achieved in the laboratory are produced by shock waves. Another phenomenon which has been known to physicists for a long time, but has only recently received attention in the popular press, appears when we try to pull astronauts back out of interplanetary space through our own atmosphere. When a capsule comes down through our own atmosphere, it produces a shock

wave ahead of it which is so strong that it builds a plasma sheath all the way around the astronaut, and our communication with the astronaut disappears.

Physicists and engineers have been spending a great deal of their time in a search for a way of producing controlled thermonuclear fusion. We all know the sun is hot—a million degrees or more on the corona. At those temperatures a controlled thermonuclear reaction is produced, as we mentioned before. We would like to be able to carry on the same reaction in a controlled fashion on the surface of the earth. The advantages would be tremendous. For one thing we are going to run out of fuel to produce power if we keep on using fossil fuel. The fission fuel is rather dangerous because radioactive products are left over after the reaction. If we went completely to fission power, we would eventually have difficulty in disposing safely of all the radioactive waste. The thermonuclear reaction has no radioactive waste. It ends up as ordinary helium. Furthermore, its fuel is a plentiful isotope of hydrogen, found in all water. Wherever human beings are, there is water, and you can burn this water to produce thermonuclear reactions. We know that a thermonuclear reaction works because the hydrogen bomb is exactly this: by exploding a fission bomb in contact with the hydrogen isotopes, you heat them so hot that the fusion reaction takes place. We would like to be able to do this in a controlled way in the laboratory; we have not yet succeeded.

It should be quite clear from this description of the plasma state that its science and technology do not fall within any one of the usual established disciplines. It is well known that the Massachusetts Institute of Technology is a place where particular disciplines do not have any very rigid boundaries. The field of plasma physics capitalizes upon the philosophy of teaching at M.I.T.

At the moment there are over 30 members of the faculty working on some phase of the plasma program. There are about 100 graduate students doing research and about 30 undergraduates absorbed into the laboratory in various ways. It is difficult to know how many courses are being taught at the graduate level because many of the courses are not of a very formal nature. However, listed in the catalog are more than 20 different courses in the plasma field, taught in many departments in both Science and Engineering. For example, in Mechanical Engineering there are courses having to do with the magnetohydrodynamic fluid flow, magnetohydrodynamic machines, shock waves, and direct energy conversion. You would expect the Electrical Engineering Department to cover a great many of these areas and they do. There is a magneto-fluid dynamics course; there are some energy conversion courses; there are microwave interaction courses that deal with radio astronomy and the structure and be-

havior of the ionosphere. In the Physics Department courses in the electrical properties of electrons and ions and the effects of magnetic fields on plasmas are taught. Also there are courses in the nonlinear phenomena in fluids and plasma and wave propagation in this new kind of medium. There is a very strong group in cosmic physics. They specialize in satellites and in making tests of the plasma nature of space in the interplanetary system, as well as in problems of radio astronomy.

As you would expect, the Department of Aeronautics and Astronautics has research teams working in various areas of this plasma group. They are interested in problems of astronaut propulsion and in high-speed flow, since many of the very high-speed phenomena occurring in plasmas are of great interest if you want to get somewhere in the universe away from the earth. The Mathematics Department has a course in mathematical theory of magneto-fluid mechanics, and our mathematicians are developing the basic mathematical tools for understanding many of the plasma phenomena on earth and in the astronomical regions of space. Finally the Nuclear Engineering Department has four courses which have to do with the thermonuclear processes which we hope will lead to a controlled thermonuclear fusion reactor. This is still in the future, but we are learning a great deal about this reaction as a potential source of power.

To me, as a teacher, one of the interesting things about suddenly opening up a new field is its effect on our teaching policies. What kind of physics do we teach our undergraduates to give them basic information for more advanced work in this field? For generations we have been dropping out things like fluid flow, but this is precisely what you need for an understanding of the fundamentals of plasma physics. As the research areas change, the change must be reflected in the more elementary educational processes.

To make progress in this direction we convened at M.I.T. a group of physicists and engineers who were basically interested in trying to teach plasma physics at an elementary level. There were some M.I.T. professors, professors from Pittsburgh, from Princeton, from Caltech, from Swarthmore, from the University of California at Berkeley, from Stanford, and some industrial physicists from Bell Labs, from Avco, and from Government laboratories like those at Los Alamos and Livermore. We worked together for a week, devising what we thought was a reasonably good course. We published it in outline form. Many of us in various places in the country are trying now to teach this undergraduate course in plasma physics, including the areas having to do with plasma astronomy, charged particle physics, magnetohydrodynamic flow, and so forth. This interuniversity cooperation is a very real attempt to develop undergraduate courses which will lay the foundations for further work in this field.

Now let me close this brief survey of a fascinating new area of physics in essentially the way I began. It is rare that scientists are suddenly faced with a whole new state of matter which they had not recognized before. The plasma physicist finds himself in this situation, riding the leading edge of science. Tremendous endeavors are generated whose influence reaches into all areas of human affairs. The sensation is exhilarating.

Anatomy of an Experiment: An Account of the Discovery of the Neutrino

By Clyde L. Cowan

Professor of Physics, Catholic University of America

[With 8 plates]

The first three decades of this century saw the absolute conservation laws and the theory of relativity take on dimensions extending from the astronomical to the atomic. But during these years a serious challenge to their general validity was also building up as a group at the Cavendish Laboratory led the work of compiling the facts of radioactivity. Of the three kinds of radioactivity known at that time—alpha, beta, and gamma decay—the first and the last were well behaved. In these, the alpha particle and the gamma ray were found to carry away from the decaying nucleus just the right amount of energy and momentum. Each time such a decay occurred, the energy lost by the decaying nucleus was to be found in the emitted particle.

For beta decay the story was very different. Although, again, the amount of energy lost by the nucleus was well known, the emitted beta particle never carried away this amount from the decay. It was intriguing that the beta particle never had too much energy, but always too little. The distribution-in-energy, called the "energy spectrum," of the beta particles from any given type of decay, when collected for many decays and plotted in a bar graph resulted in a plot typified by figure 1.

Energy was, apparently, being lost—disappearing from the universe. Otherwise, each time a beta decay occurred, the beta particle would have had *that* energy, and all would have been plotted in a single bar at the point marked "end point energy" in the figure.

THE FABLE OF THE FRUSTRATED BULLETMAKER

Consider an analogous (but totally mythical) situation: A maker of rifle bullets compounds a new gunpowder and, of course, must test it by firing a number of bullets filled with the new mixture. He mounts his test rifle on a firm stand and aims it down range. The first

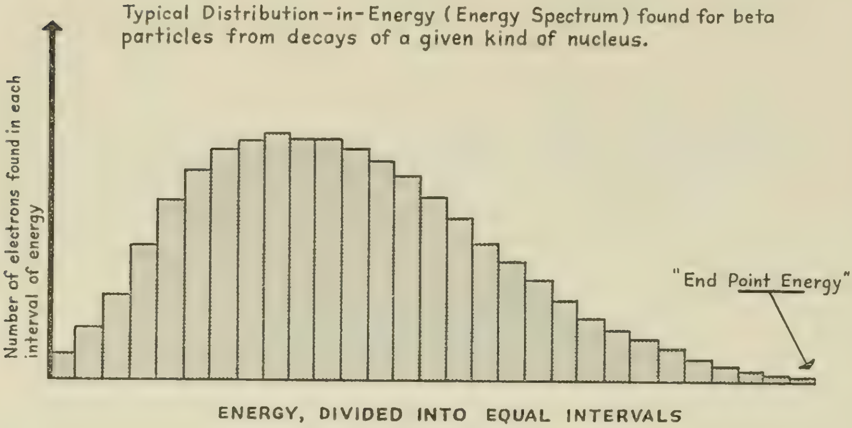

FIGURE 1

few firings are sufficient to convince him that something has gone wrong, for none of his bullets travels the expected distance. Instead, they all fall short at different distances (one even rolled out of the barrel and dropped at his feet). Puzzled, the bulletmaker takes his gun apart, but finds it to be in perfect shape. He opens a number of his shells to inspect the powder. It is dry. He fires a few more, but with the same result.

Returning to his laboratory, the bulletmaker looks into the jars and boxes of sulfur and lampblack and nitrates. He tests each—only to find them normal. He prepares more of the new mixture, fills more shells and plugs them with new bullets. He has been overly careful to weigh the same amount of powder into each shell, and as he knows the

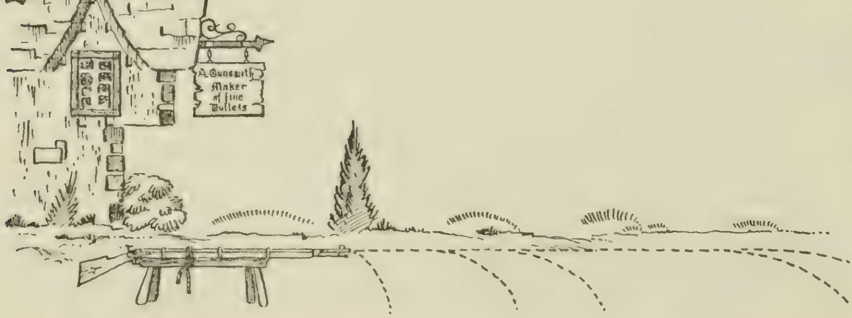

FIGURE 2

amount of energy each measure of powder has in it, he calculates again how far the charge should carry each bullet.

Back on the rifle range, the bulletmaker again fires his new bullets, and again, none goes far enough. He checks his gun again and again, then fires good, old-fashioned bullets using powder that has worked well for years. These behave perfectly. Each falls at exactly the right place. But when he tries his new powder, none of the bullets behave sensibly. He checks for gas leakage from the rifle breech. There is none. He examines the shells after firing. The powder has burned perfectly and completely. Tormented by the puzzle, the master

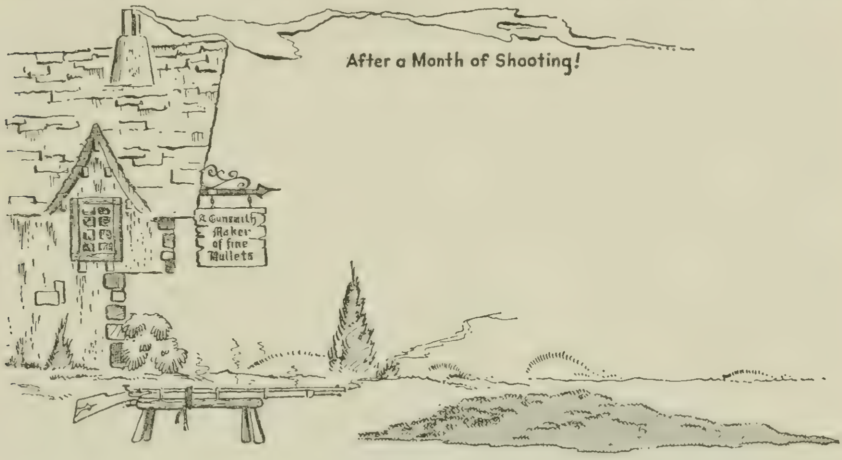

FIGURE 3

bulletmaker drives himself to discover where the loss of power is occurring. After firing bullets for some weeks, the spent bullets lie in a long continuous heap stretching down range from his gun.

By now, many of the bulletmaker's friends have heard of his strange problem and visit his rifle range to see for themselves. Of course, each has an opinion, and each is invited to correct the difficulty. They fire the bullets with their guns, but the bullets merely fall onto the growing pile. They test the powder over again, but find that it always burns completely and at the same rate. Many end by shaking their heads and declaring that the bulletmaking craft is no longer an exact science, that the familiar rules can no longer be relied upon.

One friend, however, takes a meter stick and measures the dimensions of the pile of spent bullets. He measures its depth at various distances from the gun. Then he makes a suggestion (for he doesn't want to give up the rules so readily). "Suppose *two* bullets come out of the gun at each firing with this new powder! One would be the bullet seen to fall onto the pile, and the other a very small one which travels a great distance at high speed and is not seen. The new

bullet would be 'made' at the instant of firing by the powder, and would share the energy of the powder charge with the ordinary bullet." His friends glance at one another in amusement, but he continues, "Now if this new little bullet never travels down the barrel *but always leaves the gun through the sides and back of the breech*, then we could keep our rules for the energy of a powder charge and explain the shape of the pile of spent bullets in front of us."

The idea is met with astonishment. How could any sane bulletmaker seriously propose such a wild thought as this? Surely, this is just a strained excuse for holding onto obsolete rules concerning the amount of energy available in a given weight of powder.

But another friend in the group speaks up. He says, "Let us assume that this 'ghost bullet' idea is correct. Let us write an equation which relates the distance the ordinary bullet travels with the direction of the recoil of the gun and the amount of recoil, assuming that a ghost bullet does travel off at some strange angle each time. We'll assume that the powder makes the ghost bullet as it burns."

When this is done, it is found that the same equation always describes the situation correctly. It says how the recoiling gun and the ordinary bullet are to act. They always do so. It correctly describes the shape of a pile of spent bullets. It even suggests the rules for making new powders that also behave strangely and predicts their spent-bullet pile very well.

And so the attitude of the assembly of bulletmakers changes. They say, "This man's theory is correct in telling us about the pile of bullets and the recoil of the gun. It preserves our old rules for these things."

Thus it comes to pass that the Guild of Master Bulletmakers starts making bullets once again as if they really believe in their recipes for gunpowder. Every now and then a batch of strange powder is made by accident. Then they recall the ghost bullet and say, "The little bullet is being made here, too." Sometimes they have to say that *two* little ghost bullets are being made in order to explain a particularly strange batch of powder.

When other friends ask them about the little bullet, they become a bit evasive, pointing out how accurately they can describe the funny recoils and the strung-out pile of spent bullets. "Of course, the little ghost bullet exists!" they exclaim. Then, a bit wistfully, some might be heard to say, "But it would be nice to find one someday."

PAULI'S SUGGESTION: A LITTLE GHOST PARTICLE AND THE FERMI-DIRAC THEORY

Energy was being lost from beta decay that was not to be found in the beta particle. This much was clear. There was widespread discussion of the problem, and some suggested that the laws of conservation of energy and momentum either failed when events occurred in the

small regions of the nucleus or, at best, only held on the average there. Wolfgang Pauli, however, suggested in 1931 that the rules held fast, but that there was a new, small, electrically neutral particle which was emitted simultaneously with the beta particle and which carried away the missing energy and momentum.

Unorthodox proposals such as this seldom find a friendly audience—nor did this one. In the early 1930's, few took Pauli seriously, but one who did was Enrico Fermi. Building a theory analogous to the theory of gamma decay (which describes the creation of a photon by a nucleus) but in which an electron and Pauli's little particle were produced simultaneously, Fermi succeeded in 1934 in devising an equation which described the phenomena of beta decay with uncanny accuracy. It correctly predicted the shapes of the energy spectra for various kinds of beta decay and correctly predicted the half-lives of these various radioactive nuclei. With such impressive success with Pauli's little neutral particle, Fermi suggested that it be named "neutrino."

In constructing his theory, Fermi had used the results obtained by P. A. M. Dirac in 1928 in which Dirac had succeeded in finding an equation for the electron which satisfied the theory of relativity. An unexpected result of Dirac's work was the prediction of the existence of positive electrons in nature—a prediction confirmed by the observation of "positrons" by Carl D. Anderson in 1932. Fermi applied this theory not only to the beta particle (the fast electron ejected by a decaying nucleus) but also to the neutrino. Thus, the neutrino would not only be coupled with an antineutrino in nature (as the electron is to an antielectron; the positron), but also would have an intrinsic spin angular momentum of ½ unit, the same as does the electron. In using these theoretical predictions of the Dirac equation, Fermi was building a complete conservation into his own theory: That of energy, of linear momentum, of angular momentum, of electric charge, and of "light particles" (now called "leptons").

INTERACTIONS AND THE PENETRATION OF MATTER

Natural phenomena are treated by modern physics in terms of "interactions," or basic forces which can be looked upon as causing things to happen. The "constant of gravitation," the G in Newton's equation for the gravitational attraction between two masses, is the most venerable of the "interactions" we know of in nature. Electrical phenomena are described in terms of the Coulomb interaction, and nuclear reactions in terms of a "strong" nuclear force. For his theory of beta decay, Fermi postulated yet another interaction—that which causes the decay. The strength of the interaction affects the rapidity with which a given event will occur. In radioactive decay it determines the half-life of any given radioactive species. Conversely, if the half-life is measured for a given species, and if the theoretical

expression for the decay of that species is known, then the strength of the interaction may be computed.

This experimental evaluation of Fermi's interaction was made for many different radioactive species. It was the same for each, and—what was most surprising—it was found to be extremely small compared with the other known nuclear force. For this reason, it has become known as a second kind of nuclear force termed the "weak interaction."

As it is the field of force that a particle carries along that determines how readily it will collide with other particles, the strength of this force field determines how much matter a particle will penetrate before it is stopped. Because of this, the neutrino described by the theory of Fermi turns out to be an extremely penetrating particle. All other particles known carry some or all of the other force fields with them, and so they slow down quite readily when they enter a thick layer of matter. The neutrino, on the other hand, carries only this weak field with it and so sees other particles very poorly; in fact, hardly at all.

We may give the value of the force numerically, but it might be more comprehensible if we instead interpret it in terms of how deeply a neutrino may be expected to penetrate matter. This can be done by recounting a true story involving the author and his colleague, Dr. Frederick Reines. In dreaming of ways to detect neutrinos from the sun (for the sun should be making neutrinos as it generates its own nuclear energy), we wondered how one might prove that such neutrinos actually came from the sun, once detected. The first thought was simple: Observe the signal rate at noon and at midnight, then compare the two rates. The one taken at night would require solar neutrinos to have penetrated the earth, and so the signal would be reduced by absorption in passing through the earth. We calculated the reduction to be expected, and found that the midnight rate would be indistinguishable from the noontime rate. We must have more absorber than the earth can provide! Well, let's perform the experiment during a solar eclipse, when the moon would also be an absorber for us. Still no change worth considering. Our curiosity aroused, we then calculated how many moons, all eclipsing the sun at the same time, would be required to reduce the signal by a detectable amount. We found that there isn't enough room between here and the sun to crowd in enough moons to do this! It would take a line of moons some 3 or 4 light-years long to absorb only *one* neutrino of every *two* that started through them. So small is the "weak interaction."

Another way to visualize a neutrino is by a "size." If we relate the penetrating ability of a neutrino to its size, in the sense that the smaller it is, the less likely it will be to strike anything, then the neutrino which would penetrate our long line of moons would have a cross-

sectional area of about 10^{-45} square centimeters. But this is a number so small that it is impossible to visualize. We can make the comparison with an electron, however, and say that the electron is several hundred billion billion times larger than a neutrino. The neutrino is quite surely the smallest piece of reality that has even been seriously contemplated by man.

TO CATCH A NEUTRINO

It is precisely this extreme penetrating power of a neutrino which caused them to escape from the beta decay experiments leading to Pauli's hypothesis. It is also this ability to penetrate matter which sets the main problem in trying to observe a neutrino in flight from the instant of its birth. In order to "observe" an entity like an elementary particle, the entity must react with something so as to produce an observable signal—say an electrical impulse. In the case of a neutrino, we have seen that it will penetrate astronomical thicknesses of matter before it has the opportunity to react at all. But, *given sufficient thickness of matter*, it will react. And here is the key to the detection problem. For, if instead of asking for one neutrino to react with a great thickness, we can turn the question around and supply a reasonable thickness and ask for an astronomical number of neutrinos to be incident upon it. Then we can hope to detect interactions in this matter.

In the years following the hypothesis of Pauli and the theory of Fermi, such attempts were made, but not nearly enough radioactive material was available to supply the astronomical number of neutrinos required. Attention then turned to the investigation of those aspects of beta decay which *were* observable. Measurements of beta spectra and lifetimes were refined greatly. The theory itself was refined to account for some deviations found, and it began to yield a deepening insight into the nature of the elementary particles.

The search for the neutrino turned to indirect methods. Careful measurements both of the beta particle momentum and the recoil of the nucleus were made. It turned out that, within the accuracy attainable, the two particles, nucleus and electron, recoiled from the site of the decay just as if a neutrino had shot off in some other direction. Thus, if a neutrino *did* shoot off as the theory said, the conservation laws still held true. These observations of conservation of energy and momentum, *assuming* the existence of a neutrino, became a popular argument *for* the existence of the tiny particle. The concept of the neutrino had been developed to save the conservation laws. The fact that the concept then permitted their retention—as it must if the algebra is worked correctly—was then taken as proof of the existence of the neutrino. This circular reasoning is the sort that postulates the existence of a poltergeist to explain the unattended movement of a

chair across the room, then takes the observed movement of the chair as proof of the existence of the poltergeist.

The story of these exciting times and the ingenious and painstaking efforts made to test the neutrino hypothesis is told at length in the technical and popular literature, an introduction to which is given as a part of the bibliography More detailed and complete accounts of the properties of the neutrino as anticipated before its observation and as they have developed since that time are also to be found there. Suffice it to say that physics had a genuine poltergeist in its house by the time the 1950's were drawing to an end, for by then a considerable list of reactions of the elementary particles called upon this ghostly particle to help conserve the conservation laws.

PROJECT POLTERGEIST—I

We have said that the extreme reluctance of the hypothesized neutrino to interact and so reveal itself might be overcome if an astronomical number of such reluctant particles were allowed to fall on a reasonable amount of absorber. Such astronomical quantities were presumably becoming available during the years following World War II, if indeed neutrinos did exist, as nuclear explosions were set off from time-to-time. These explosions of fissioning uranium and plutonium resulted in great concentrations of radioactive nuclei, known as "fission fragments." In general, the fission of one atom of uranium will produce a chain of some six or more radioactive decays, each one a beta decay. Thus, each fission should produce on the average some six or more neutrinos.

Here we must particularize somewhat. We have said that Fermi's applications of Dirac's equations to his theory would predict that both neutrinos and antineutrinos are made in nature. Just what the difference between the two sorts of neutrino might be was not understood at that time, except that beta decay which produces negative electrons as beta particles must also produce antineutrinos, while beta decay producing positrons would produce neutrinos. And as all the radioactive fission fragments being made in the nuclear explosions resulted in *negatron* decays, then the six small partners from these decays must be *antineutrinos.*

We also have said that the only field the neutrino (let us continue to use this word to indicate both sorts, except where it is necessary to specify one kind only) carries with it is the weak field which causes beta decay. This means that the only reaction one can reasonably expect the neutrino to produce is another beta decay. Such a forced decay, if made by neutrinos in a detector, would constitute the first synthetic beta decay and would signal the possible capture of a neutrino. To tag the neutrino as the culprit which stole the energy from

a given decaying nucleus, one must find that energy in the particle and show that it came from the site of the theft. If theory was correct, there were plenty of these small culprits fleeing from the decaying nuclei in a nuclear explosion fireball so that one could hope to catch a few of them.

Frederick Reines and the author resolved to attempt this. As a signal of the capture of an antineutrino in flight, we would ask for the radioactive decay of a proton. Now protons, most familiar as nuclei of ordinary hydrogen, are among the most stable objects known—they never decay spontaneously. If one should capture an antineutrino, however, it would be forced into changing into a neutron by emission of a positive beta particle, a positron.

Thus, if one detects protons emitting positrons, then one has every reason to believe that an antineutrino has been captured. We calculated that we could provide enough protons (as hydrogen atoms) in a few hundred gallons of an organic liquid so that a few hundred such positrons should be produced by antineutrinos coming from a nuclear fireball—if we could get the liquid close enough to the fireball.

Two problems were raised by this conclusion, however: (1) How could a few hundred positrons be detected when released in several hundred gallons of liquid; and (2) how could such a detector, once built, be placed close enough to the violence of a nuclear explosion and survive to tell the story?

By "close enough," we calculated that it must be at least within 200 feet or so from the base of a tower on which a 20-kiloton explosion was fired. Such towers are usually about 100 feet high. We set about finding answers to these questions.

For the first problem, there was already a lead. Certain organic liquids had been found which when purified and then contaminated with traces of particular compounds become sensitive to the passage of fast electrons. They "scintillate"—they emit short bursts of light. These bursts are extremely weak, but what intensity they have is proportional to the range (therefore, the energy) of the electron passing through them. These bursts of light are detected by highly sensitive phototubes which in turn produce pulses of electricity. This lead was partial, however, for at that time (1950) such organic liquid scintillators had only been made and used in small quantities. To see into several hundred gallons of it would require some additional effort.

To test this possibility, Reines and I (both of us were working at the Los Alamos Scientific Laboratory at the time) built a large bipyramidal brass tank, of about 1 cubic meter in volume, and mounted four photomultiplier tubes at the two opposing apexes. We filled this tank (now named El Monstro) with very pure toluene activated so

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that it would scintillate. Tests using radioactive sources of electrons and gamma rays showed us that the scheme could be made to work, and that we could "see" into almost any size container we wished to use.

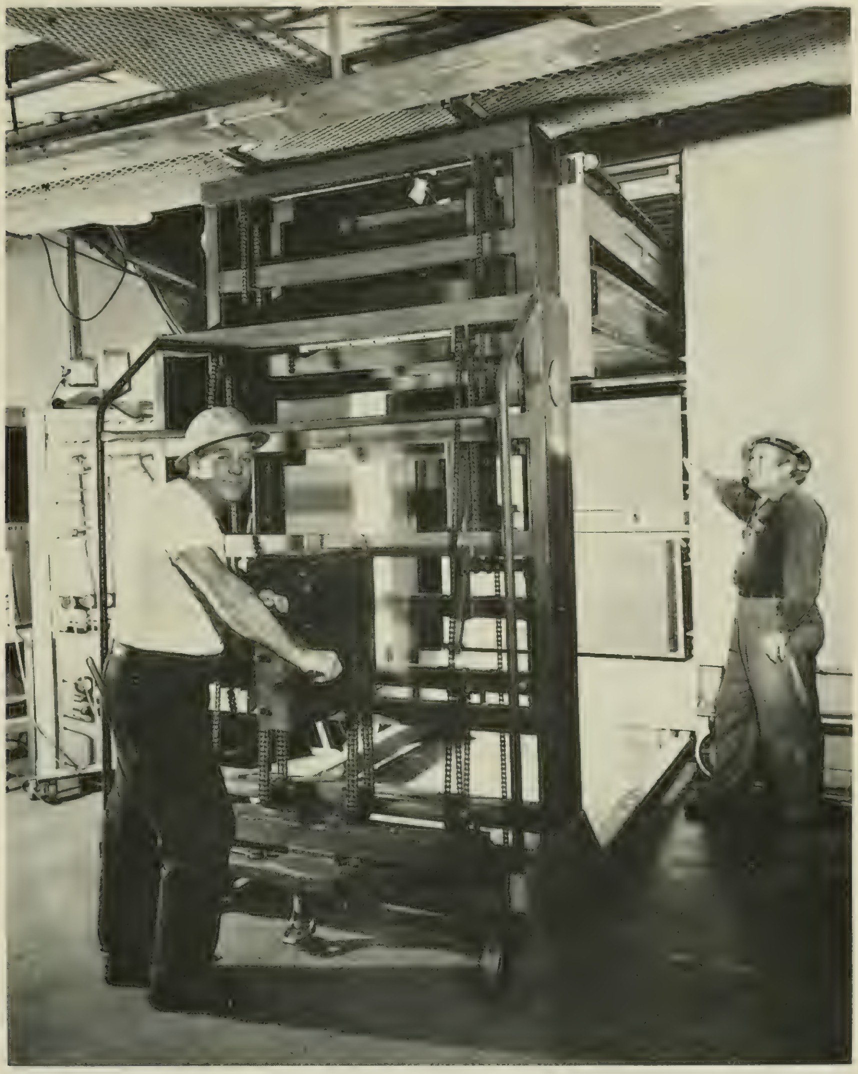
The second problem was a stickler. The extreme violence of a large nuclear explosion, accompanied by a searing heat wave and vast numbers of gamma rays and neutrons, was hardly reduced at all at a distance of several hundred feet. A detector placed on the ground at that distance would be melted, torn apart, and scattered in small pieces over the countryside. We could put it into a heavy concrete blockhouse, but the shock alone would still damage it beyond use, and only a few neutrons leaking through the walls would completely obscure our hoped-for-signal. We would have to shield it by at least a hundred feet of earth from the ordinary neutrons and gamma rays to reduce their intensity sufficiently.

The plan evolved was finally this: We would dig a shaft near "ground zero" about 10 feet in diameter and about 150 feet deep. We would put a tank, 10 feet in diameter and about 75 feet long on end at the bottom of the shaft. We would then suspend our detector from the top of the tank, along with its recording apparatus, and back-fill the shaft above the tank.

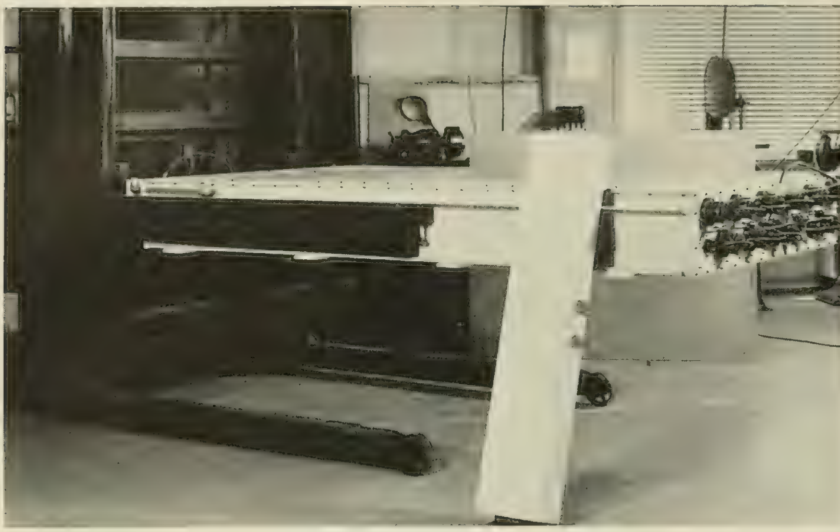
As the time for the explosion approached, we would start vacuum pumps and evacuate the tank as highly as possible. Then, when the countdown reached "zero," we would break the suspension with a small explosive, allowing the detector to fall freely in the vacuum. For about 2 seconds, the falling detector would be seeing antineutrinos and recording the pulses from them while the earth shock passed harmlessly by, rattling the tank mightily but not disturbing our falling detector. When all was relatively quiet, the detector would reach the bottom of the tank, landing on a thick pile of foam rubber and feathers (fig. 4).

We would return to the site of the shaft in a few days (when the surface radioactivity had died away sufficiently) and dig down to the tank, recover the detector, and know the truth about neutrinos! We did a lot of thinking about this matter before we broached the idea to anyone. Our first conversation on the matter was with Enrico Fermi. He questioned us closely and examined our plan in detail. His was the first encouragement we received for our plan, and we felt that the race was at least half won at that point. We approached the laboratory director, Norris Bradbury, and received more encouragement—plus permission to proceed! Assembling a group of physicists, engineers, and technicians from around the laboratory who were sufficiently intrigued by the project to take on work additional to their own, we set out to catch a neutrino.

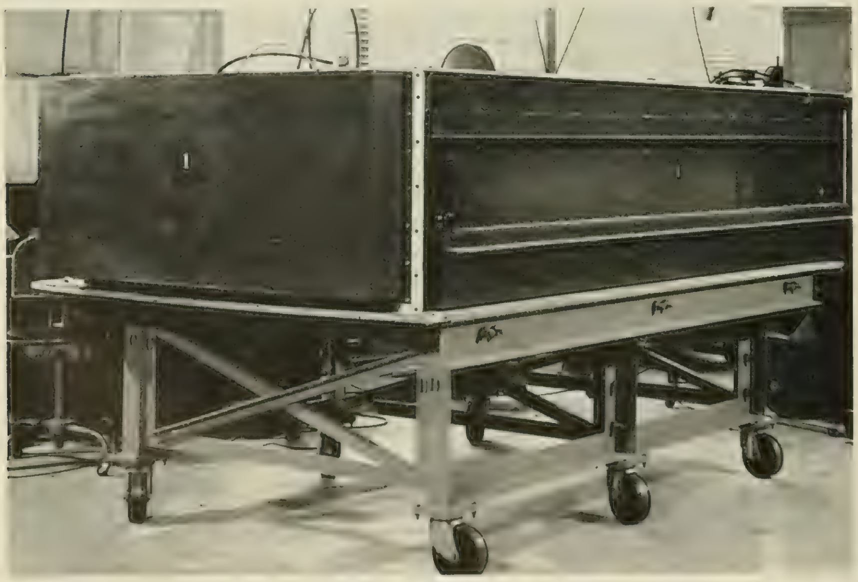
As it made little difference precisely where we placed our shaft, we chose to put it 137 feet from the base of the tower for luck. (If



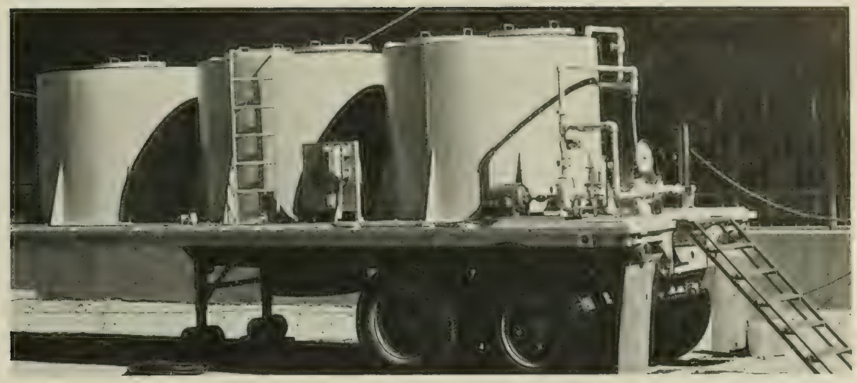
Richard Jones (left) and Martin Warren (right), two members of our team from Los Alamos, use the special fork lift to insert the top target tank into the detector shield at the Savannah River Plant reactor. Heavy lead doors behind Warren move by hydraulic control to cover the detector when it is operated. A rack of preamplifiers are seen behind Jones. These amplified the small voltage pulses obtained from the tubes and sent them through coaxial cables to the electronics trailer parked outside the reactor building.



1. One of the thin "meat" tanks for the "double-decker club sandwich" detector. This tank, containing scintillating solution and a cadmium salt, was used for analysis of the detector and calibration of its performance. It was replaced by a tank of water and cadmium acetate (later heavy-water and cadmium acetate) for the measurement at the reactor. There were, of course, two of these target tanks in the detector. It is shown resting in a special fork-lift built to handle the detector sections.

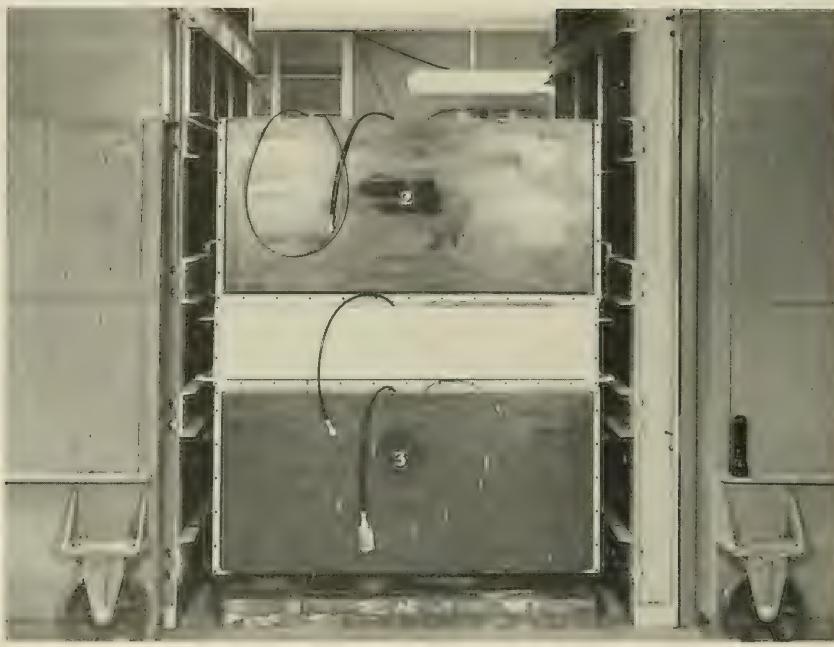


2. A completed detector section ready for insertion in the shield. The tank is made of steel plate, with the exception of the bottom. This is a cellular aluminum structure, similar to aircraft skin sections, which provides strength against bending while affording little obstruction to the entry of gamma rays from below.

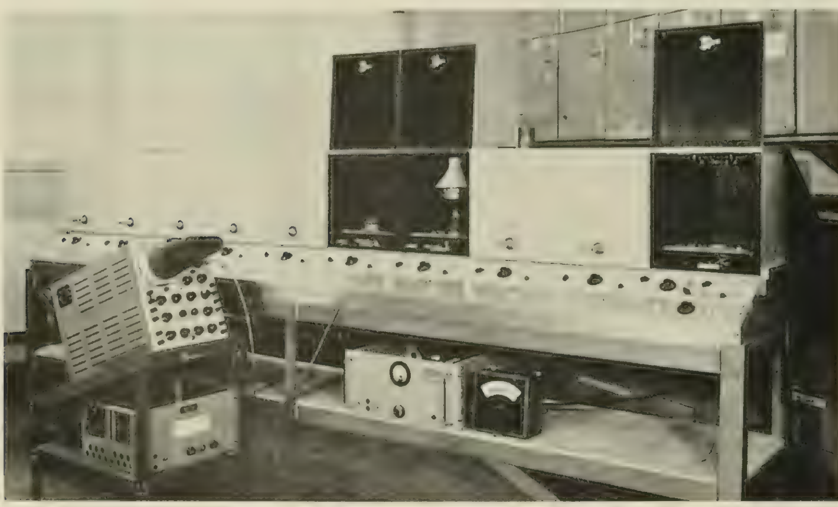


1. Three 1,200-gallon steel tanks on a flat-bed trailer comprise our tank farm. With a network of stainless-steel pipes and valves, along with special pumps, the apparatus was used to mix and transport our load of scintillating solution from Los Alamos to the Savannah River Plant. The tanks are coated with epoxy on their interiors and were later wrapped with layers of electrical heating strips on their outsides, then covered with fiber-glass insulation. On the trip to South Carolina, they were plugged into the electrical outlets of kindly filling-station operators to warm up overnight; they kept sufficient heat during the next day's run to preserve the solution.

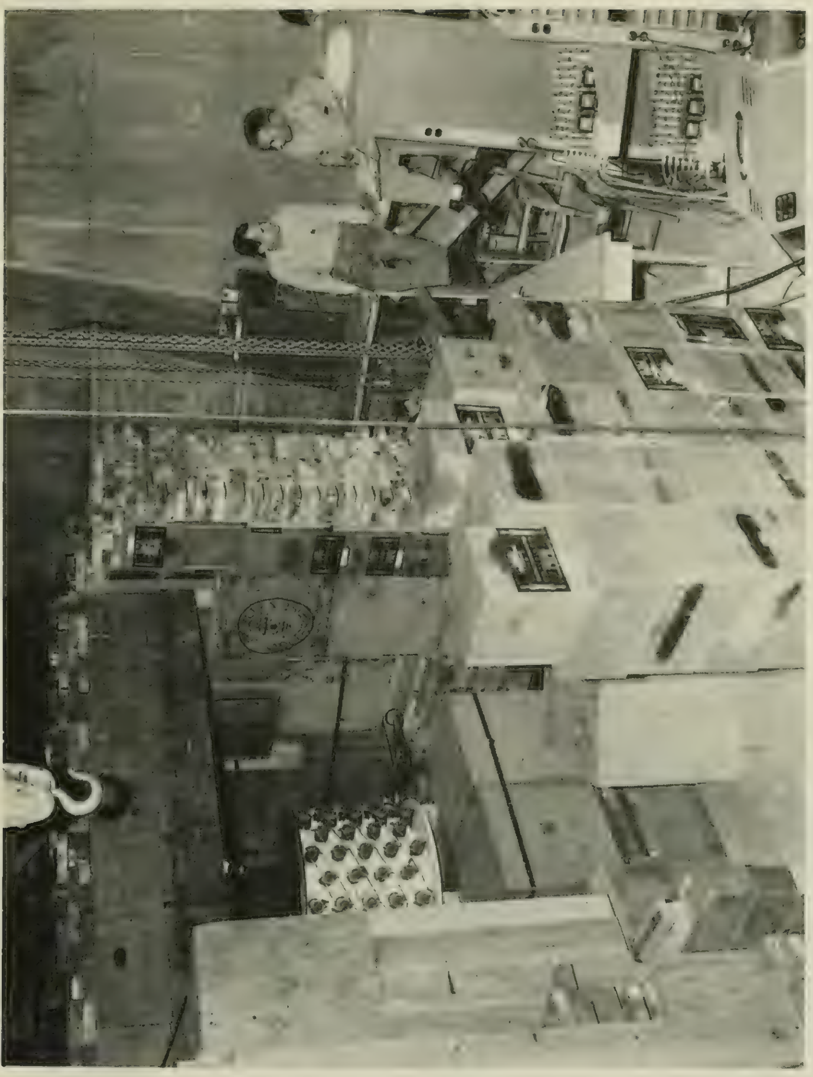
2. The final test of our signal was to shield the entire detector even more so than neutrons and gamma rays would be further attenuated. The signal, however, did not change, unless the reactor was turned off. The shield, shown here, consisted of many bags of sawdust, saturated with water, and had a mean density of 0.5. It was over 4 feet thick at all places. A pound of hominy grits, placed near the center of this face of the shield, completed it in a little ceremony in salute to our southern hosts.



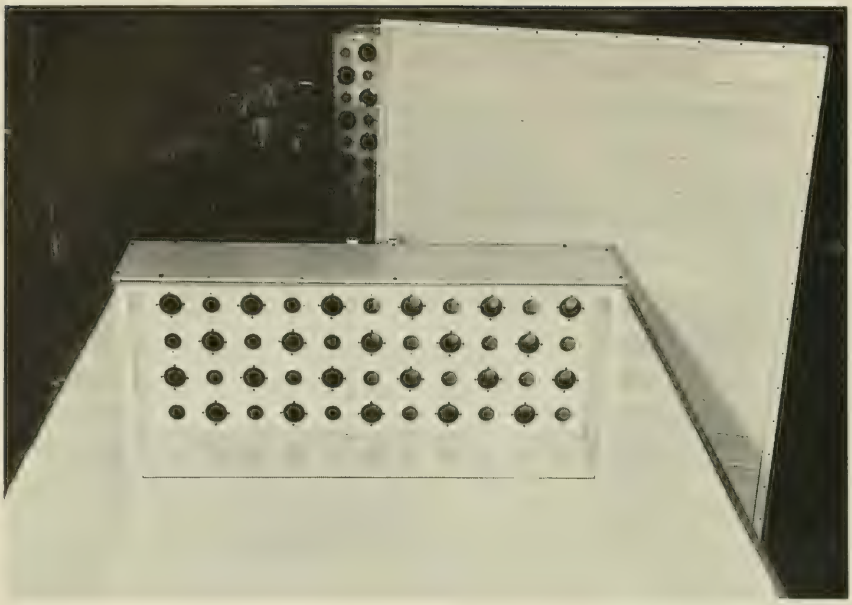
1. The lower "triad" of detectors of the system used at the Savannah River Plant rests in its lead shield ready for test at the Los Alamos Scientific Laboratory. The dark rectangles labeled "2" and "3" are the ends of the large liquid scintillation tanks which were to form the "bread" of the club-sandwich-detector. The target liquid is in the white center tank.



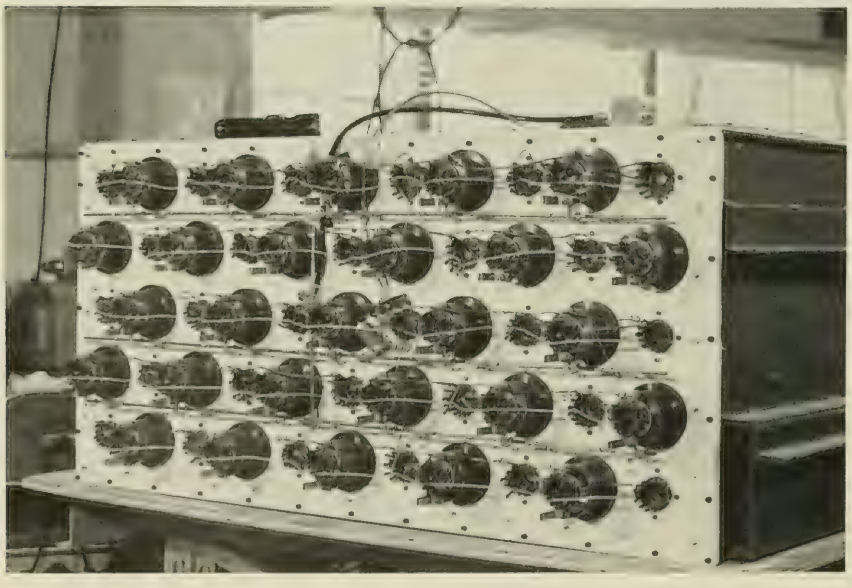
2. This multichamber dark-box was built to put each of the many photomultiplier tubes through a rigorous testing and balancing procedure before use in the detector. Three chambers are shown opened, and a photomultiplier with a sodium iodide crystal may be seen in one of them. The tubes were thus carefully selected for uniformity and stability from a large number of candidates.



Dr. N. Hayes and the author discuss a problem amid the jumble of the Hanford neutrino search. The detector is partly visible in its incomplete shield of lead and of boxes of a paraffin-borax mixture. The face of the Hanford reactor is just off the picture to the left.



1. A view of the interior of one of the large liquid scintillation tanks before mounting the photomultipliers in the end. A plexiglass sheet seals off the end forming a chamber which will contain the tubes. The thin, corrugated, stainless-steel top for the tank is seen resting behind it.



2. Exterior view of the end of a scintillation tank after mounting photomultipliers. The tube mounts and bases are seen protruding from the end. After wiring the bases into a circuit, a steel box cover was bolted in place over the end.

One of the 112 photomultiplier tubes used in each large tank, shown with its mounting socket. The 5-inch diameter face, equivalent to perhaps 100 human eyes, contains a thin, photosensitive surface. When a photon of light falls on it, an electron is ejected from the surface toward the interior of the tube. The electron strikes the first metal element known as a "dynode" where it splashes several more electrons out of the metal. These, in turn, repeat this over some nine more dynodes, multiplying the number each time until, finally, several million electrons appear at the base for each one started from the tube face. These produce a pulse of voltage in the circuit at the base which is then amplified and analyzed by the equipment farther along the line.

Dr. Frederick Reines (far right) and the author (pointing) explain the design of the scintillation tank to a visitor to the Los Alamos Scientific Laboratory. The tank rests in a tilting-frame so that assembly may be completed.

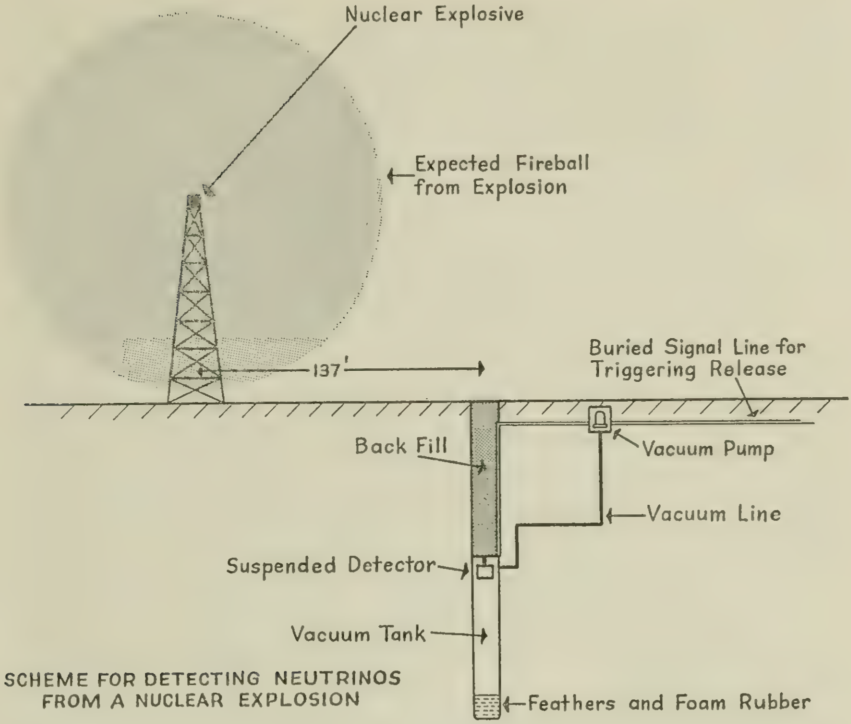


FIGURE 4

you think that physicists are not superstitious, just ask one about the number 137 sometime. He'll be evasive and say, "Oh, you mean 1/137, the fine structure constant." Press him to explain it, however, and you'll see what I mean.) We arranged for the drilling of a hole and the taking of cores at the nuclear test site in Nevada to explore the underground conditions there. Arrangements also were made to measure ground shocks and neutron backgrounds at various depths in the hole during forthcoming nuclear explosions so that we could plan more specifically. Our group began work on the problems of light transmission over long paths in the scintillator liquids, the operation of large banks of photomultiplier tubes, and the design of the great vacuum tank and its release mechanism.

But then we stopped the work suddenly, for a better idea had occurred to us.

PROJECT POLTERGEIST—II

It was a late evening in the fall of 1952. Reines and I had addressed a seminar of the Laboratory's Physics Division that afternoon, describing the progress of the work and our latest plans. At the end, Dr. J. M. B. Kellogg, Chairman of the Division, had suggested that we re-

view the problem just once more to see if we could possibly use the neutrinos emitted by a fission reactor rather than those from a fission explosion. We knew that the flux of neutrinos from even the largest of reactors would be thousands of times less than that from an explosion, while the background noise from neutrons and gamma rays would be about the same with the available shielding. Nevertheless, we sat late into the evening going over every estimate. Then the thought struck!

We were planning to force protons to undergo beta decay by absorption of antineutrinos. This decay would be the emission of a positron as the proton was changed into a neutron. The positron, being an antielectron, would be captured quickly by one of the ordinary electrons in the atoms of the liquid, both positron and electron would vanish, and two 0.51 Mev. (million electron volts) gamma rays would be produced. These gamma rays were to constitute our signal, as they, in turn, bounced off other electrons in the liquid, making it scintillate. The neutron, we knew, would also bounce around in the liquid as it struck protons and lost its energy to them, then would drift about for many microseconds before finally being captured by a proton to form deuterium, or heavy hydrogen. The neutron-proton capture would release a gamma ray of 2.2 Mev., but we had planned to use this gamma ray only as an independent signal to increase the detection efficiency somewhat.

Suddenly, we realized that if we could manage to dissolve a cadmium salt in our liquid, then the neutron would be captured more quickly (as cadmium has a much greater "cross section" for neutron capture than has hydrogen), and we could mark a neutrino signal by *two* characteristic bursts of gamma radiation which followed one another by a few microseconds: First, the two 0.51 Mev. gammas from positron-electron annihilation, then a burst of gammas totaling about 9 Mev. as the neutron was captured by cadium. This unique set of signals would provide us with a powerful discrimination against the backgrounds from a reactor. It would then be possible to use the much weaker but calmer neutrino fluxes emitted by a reactor. Instead of detecting a burst of neutrinos in a second or two coming from the fury of a nuclear explosion, we would now be able to watch patiently near a reactor and catch one every few hours or so. And there are many hours available for watching in a month—or a year.

A new plan and a first try

We called a meeting of our group the following day and set about devising a plan for work near a reactor. The road ahead now looked much clearer, and we felt that we were finally closing in on our quarry.

During the winter of 1952 we built two cylindrical detectors, each about 30 inches high and 28 inches in diameter. We mounted 90 photomultipliers around the curved walls of each and filled them with

liquid scintillator made of toluene. We learned how to connect these tubes into two interleaved banks for operation in coincidence to reduce the spurious "dark-current" signals generated by the tubes themselves. As for the cadmium salt, we found that the propionate of cadmium would dissolve in the scintillator quite well without reducing its light output seriously.

The winter was spent in testing the system in an isolated and unheated building while keeping the detector warm with several electrical bowl fires. Some of our group swept the snow away from outside the building and set about casting many large blocks of paraffin wax and borax for use as neutron shielding when we would go to a reactor. Others began mixing gallons of liquid scintillator in batches with varying composition. We found that we could also make a scintillating liquid from just one of the several brands of mineral oil carried by the local druggists. This would give us a different hydrogen density in our detector from that of toluene, allowing us to test the fact that it is a proton which reacts to yield a neutrino signal. We ordered several barrels of the oil, and this was duly mixed with the chemicals to make it scintillate.

It was during this testing period that we also investigated the radioactive content of the materials which were used to construct the detectors. We built a cylindrical well into one of the detectors and proceeded to put quantities of steel, liquids, wax, and other materials into it for testing. We found that brass and aluminum were quite radioactive compared to iron and steel, and that the potassium in the glass envelopes of our photomultiplier tubes would contribute to the detector backgrounds. By putting the detector "into itself" in this manner, piece-by-piece, we were able to avoid the more seriously contaminated materials in its construction.

During this time, one of our group, Robert Shuch, proposed making the well in the detector a bit larger so that we might be able to put a human being into the detector. This was done, and a number of people, including our secretary, were trussed up and lowered into the 18-inch hole. We found quite a detectable counting rate from everyone. It was due to the radioactive potassium-40 naturally present in the body. Using small radium sources strapped near the navel of a subject, we found that extremely minute quantities of radioactive contaminants were measurable in the human body. This brief interlude thus saw the birth of the total-immersion, or "whole-body" counter. The two neutrino detectors were later to be placed into service as the first of many such large clinical and medical research counters.

In the very early spring of 1953 we set out for Hanford, Wash., where the largest and newest of the country's fission reactors was just being put into operation. The work at Hanford, while tedious in

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the doing, need not be so in the telling. We put our detector very close to the face of the reactor wall, piling all of our shielding around it and all the lead that was available at the Hanford plant until the floor sagged, and then we "listened." We restacked our shield and listened again for the double pulses signaling neutrinos when the reactor was operating. (See pl. 5.)

The lesson of the work was clear: It is easy to shield out the noise men make, but impossible to shut out the cosmos. Neutrons and gamma rays from the reactor, which we had feared most, were stopped in our thick walls of paraffin, borax, and lead, but the cosmic ray mesons penetrated gleefully, generating backgrounds in our equipment as they passed or stopped in it. We had brought large trays of geiger counters to place around and over the detector, so that cosmic rays could be identified as such and rejected from the signal rate.

We did record neutrinolike signals which, seen in retrospect, were genuine. They appeared and disappeared as the reactor was raised to power and then shut down again. But the cosmic rays with their neutron secondaries generated in our shield were some 10 times more abundant than were the neutrino signals. Under these circumstances, it was quite impossible to test the neutrino signal by changing the number of proton targets in the detector or by altering the cadmium concentration to alter the neutron capture times as we had planned.

We felt that we had the neutrino by its coattails, but our evidence would not yet stand up in court. We must be more clever than this. We returned to Los Alamos with a gleam in our eyes, for we felt that now we knew how to catch the neutrino.

PROJECT POLTERGEIST—III

It was time to become serious about Project Poltergeist, and so the Laboratory suggested that we set up a formal group for the sole purpose of tracking neutrinos. This we did, taking with us those of the original team who could leave their other work behind, and recruiting several new members to the group.

Looking again at the reaction which signals the capture of an antineutrino, we recall that the capture of the particle by a proton changes the proton into a neutron with the emission of a positron. We had used the *time correlation* of the two pulses produced by positron annihilation and by neutron capture in hydrogen. We would now use the *spatial correlation* of the various gamma rays as well. This would give us a great advantage over the spurious signals produced by the cosmic rays.

A new detector was designed in which a large thin tank of water supplied the proton targets, and cadmium acetate dissolved in the water lay in wait to capture the neutrons produced. Positron annihilation results in two 0.51 Mev. gamma rays which travel away from

the annihilation in opposite directions. Thus, quite often one gamma ray would emerge from the top of the water slab, and the other from the bottom. Neutron capture in cadmium produces a burst of many gamma rays which total about 9 Mev. in energy. These also would emerge from both top and bottom of the slab. By placing large thick tanks of liquid scintillator on either side of the water slab, we could expect to see these events in top-bottom coincidence as well as in time-delayed correlation. A detector of this description was designed but, in a sense, was made twofold. We designed two such slabs and placed them between three thick liquid scintillator detectors, much as the meat is placed between three slices of bread in a club sandwich. This would provide a running check on the equipment, as both detectors must operate in agreement as to what they see. (See pl. 4, fig. 1.)

Another year's work at Los Alamos went into the construction and testing of the new detector. Dr. John Wheeler suggested during that time that we make our next measurement at the new Savannah River Plant and arranged for our visit to that laboratory. With the cooperation of the Du Pont scientists there we quickly found an almost ideal spot near one of their reactors. During the year we also developed a new scintillating solution (of triethylbenzene) which was much less hazardous than toluene. (See pl. 4, fig. 2.)

When completed and sitting in its great lead shield in the physics building at Los Alamos, the detector was about 10 feet high. It occupied a floorspace some 6 feet by 12 feet. The shield around it was made of a steel framework holding walls of lead 6 inches thick. The lead top and bottom were also of this thickness, and hydraulically operated lead doors some 4 inches thick closed the two ends. Three separate scintillation detectors were stacked inside the shield, and between each pair was a flat tank of water and cadmium acetate as a target.

The detectors were made of rectangular steel tanks which held the liquid scintillator in their center sections. Each was 2 feet thick, about 4 feet wide, and some 11 feet long. Each center section of scintillator was 6 feet long. End sections were filled with a clear, nonscintillating liquid to act as shields against radioactivity from the banks of photomultipliers looking in from each end. There were 55 photomultipliers on each end of each of the 3 detectors. Each photomultiplier was a large 5-inch diameter "eye" which stared fixedly at the sensitive liquid in the tank and reported the faint flashes of light there with electrical pulses. The "compound eye" of the total detector thus had a retinal area greater than 45 square feet. Each of the photomultipliers had been carefully selected and its sensitivity balanced to a standard value. The tanks were painted white inside to conserve every photon possible and reflect it toward the phototubes. (See pls. 2, 6, 7, and 8.)

As the spot chosen at the Savannah River Plant reactor was only large enough to hold the detector, we would have to send the electrical pulses from it to the equipment some distance away. We decided to build all of our electronic gear into a large trailer which would then act as our laboratory. Holding amplifiers, coincidence and gating circuits, scalers and recording equipment, some 12 racks finally lined one side of the trailer from floor to ceiling. A blower and conduit outside the trailer served to keep the equipment cool while it was operating.

To prepare and handle the liquid scintillator, a "tank farm" was built on a flat bed trailer. This consisted of three steel tanks, each of 1200-gallon capacity. The tanks were coated on their interior surfaces with an epoxy paint to preserve the purity of the liquids and were wrapped with several layers of insulating material on their outsides. As the tanks must never be allowed to fall below about 60° F. when they contain scintillator, long strips of electrical heating elements were embedded in the exterior insulation. A network of stainless steel pipe, valves, and pumps complete the tank farm. (See pl. 3.)

The year was spent in building and testing. It was important that we know the details of the performance of our system quite well before we left home. The effects of the ever-present cosmic ray muons were also determined in great detail.

In November 1955, we were ready to leave Los Alamos again in quest of neutrinos. Early one morning, after a blessing of the group and its equipment by Father Francis Schuler, the Catholic pastor of the parish at Los Alamos, in the ancient Latin phrases that down through the centuries have sent men across the world in search of knowledge and adventure, our little convoy snaked down the mountainside and set out for South Carolina.

The work at the Savannah River Plant

The new year found our detector installed near the great reactor, with its pipes and bundles of wires and coaxial cables running to the laboratory and tank farm trailers parked outside. Calibrations were undertaken using artificial radioactive sources and the cosmic rays, and backgrounds were measured in the myriad different forms they assume in such equipment. By early spring we felt that we were ready for our quarry. (See pl. 1.)

The bait that we were using was hydrogen—or rather the nuclei of hydrogen, protons. Let us review the anticipated reaction and the signals produced which would demonstrate that antineutrinos were, in truth, coming from the reactor. Of the several hundred million billion antineutrinos which should (according to theory and the known power level of the reactor) be streaming through our detector each

second, virtually all would pass through as if the detector were not there. Several times each hour, however, one antineutrino would react with a proton—the nucleus of a hydrogen atom in one or the other H_2O target tank. When this occurred, a fast positron would be emitted by the proton, and the proton would then be a moderately fast neutron as it recoiled from the site of the event. We knew what the energy spectrum of the antineutrinos coming from the reactor should be, because we knew quite a bit about the various radioactive fission fragment nuclei being formed in it, and we had Fermi's theory to guide us from there. We knew, for instance, that about 10^{-13} antineutrinos should strike each square centimeter of our water target per second, that the effective energy of these antineutrinos should be about 3 Mev., and that the cross section presented by each proton in the water hydrogen to each antineutrino would be about 10^{-43} square centimeters.

After an antineutrino had reacted with a proton, the positron would slow to a stop very quickly in the water, would capture an electron from near where it stopped, and then the two would combine to produce two 0.51 Mev. gamma rays. Suppose this happened in the top water target. Then one gamma would pass into the top scintillator, producing a flash of light there, while the other would do the same—at the same time—in the center scintillator. A pair of pulses would then be recorded by our equipment as having occurred "in coincidence," and the electronics would be alerted by this and start to watch for a second signal produced by the neutron.

The neutron would leave the site of the event with a few Kev. energy, and, being much heavier than the positron, would slow down much more reluctantly. Nevertheless, the neutron would be of "thermal" energy in about 2 microseconds and would then drift about in the water until it happened close to a cadmium nucleus. Let us imagine that this would be about 4 microseconds later. One of the cadmium isotopes has a strong affinity for neutrons that are just drifting about with little energy. The neutron is quickly captured by the cadmium, and a burst of gamma rays then is emitted by the cadmium nucleus. Again, some of these would pass into the top scintillator, some into the center. Flashes of light would again be detected as they produced pulses of electricity in the equipment. We know the total energy of the cadmium gamma rays when it captures a neutron, so the total light produced should be just the right amount. So also, should the *total* electrical pulse voltage, i.e., the sum of the two electrical pulses.

Thus, a set of four pulses (two of the right amplitude each, followed in 6 microseconds by two of the right total amplitude) would be fed into the electronic racks in the trailer. This particular pattern is very distinctive and is not very likely to occur by accident or by any other sort of nuclear interaction in the detector. Among the

many electrical pulses which rattle through the electronic equipment each second from other causes, this one pattern can be picked out by the equipment very nicely.

In addition to going to the electronic analysis equipment, our set of pulses from the top scintillator has also been sent down a long transmission line, wrapped back and forth inside the trailer. They take 10 microseconds to emerge from the other end. They are then sent to an oscilloscope. The electronic equipment, having sensed the possibility of an interesting pattern, signals to the oscilloscope when it sees the second pair of pulses, and the electron beam of the cathode ray tube starts to trace a line of light across the tube face. It will take 20 microseconds to traverse the tube face.

Thus, 4 microseconds later (10 for the time spent in the transmission line minus 6 while waiting for the neutron signal), the positron pulse from the top scintillator tank emerges from the line and causes the electron beam to deflect upward briefly, then return to its steady sweep across the face of the tube. The amount of deflection of the beam during the pulse is proportional to the energy deposited in the tank, and this is known from our calibration work. Six microseconds later, the neutron pulse arrives from the same top tank. It also deflects the beam briefly, proportional to its amplitude. The beam then completes its track across the remaining part of the tube face, and it is turned off to wait for another interesting event to send it on its brief trip.

All this has occurred for those signals coming from the top tank. Exactly the same has occurred for those from the center tank of scintillator as well. The pulses from the center tank have passed down their own transmission line and then to the oscilloscope to cause another beam in the same tube to deflect. Its track lies below the first beam so as not to obscure it. The bottom tank is connected as well to a third transmission line and then to a third beam in the tube. But no signals came from this tank in our example described here, so its beam has just swept undeflected across the oscilloscope face.

During this time a 35 mm. camera loaded with 100 feet of film has been watching the tube face with its shutter permanently open, so that the streaks of light which appeared there are now recorded on one frame of film. After the action has finished, the camera motor advances the film to a fresh frame.

Thus were the signals from the three tanks sorted out, analyzed, and recorded on film whenever they occurred in a pattern which *may* have been due to the capture of an antineutrino in the detector. Two triple-beam oscilloscopes were used in parallel, as described above, so that one operating at low gain could look for large pulses while the other operated at higher gain to record the smaller pulses. Each

day the films would be removed and developed for reading. At that time tests would be made of the detector and electronic system to catch any changes that might have occurred.

THE FIVE ELEMENTS OF PROOF

Having the equipment operate as planned near the reactor and observing the correct patterns of pulses now and then was most satisfying. But now the work remained to test these signals to ascertain whether or not they were in fact produced by antineutrinos from the reactor. Five experiments were performed using these pulses, with objectives as listed below:

1. The rate at which they were recorded must be correct, knowing the reactor power and detector efficiency. This rate must drop to zero (or to a relatively low and well-understood background) when the reactor is shut down.
2. The first pair of pulses must be shown to be due to the annihilation of a positron by an electron.
3. The second pair of pulses must be shown to be due to the capture of a neutron by cadmium, and the neutron must have appeared in the detector at the same instant as did the positron.
4. The signal rate must be proportional to the number of protons in the water target tanks. If the amount of hydrogen is changed, the signal rate must change accordingly.
5. The signal, when shown to be associated with the reactor being run, must be shown to be independent of gamma rays and neutrons leaking from the reactor shield.

The following months saw these tests undertaken. In each test, the two water tanks operated as independent targets, and the data obtained from each were analyzed and required to check one another. The checks were made in various, sometimes redundant, ways, in order to apply every test we could devise. The details of these checks and the resulting data are reported in the relevant papers listed in the bibliography, and will be described only in general terms here.

Dependence of the signal rate on reactor power.—This is the easiest to describe. The equipment was operated for 893.5 hours (in two separate runs) with the reactor on, and for 263.4 hours (again, in two separate runs) with the reactor off. With the reactor on, the signal rate was about 1.8 per hour, and with the reactor off, it was about one-fifth of this. This background rate was understood in terms of cosmic ray interferences, similar to the ones which had forced us to stop work at Hanford. But there, the cosmic ray backgrounds were some 10 times *higher* than the signal rate produced by the reactor. We could also work our data "in reverse," calculating a cross section for the reaction from them, then comparing it with the theoretical one. The two—experimental and theoretical—agreed

well within the limits imposed by statistical fluctuations and lack of absolute knowledge concerning the neutrino spectrum.

Evidence that the first pulse pair was due to a positron.—Here we had two checks. We had dissolved a known positron-emitting radioactive material (copper-64) in the water of a target tank and observed the pulse amplitude spectrum obtained from it. The spectrum of pulses in the first pair of reactor-produced events agreed with it nicely. The second check consisted of placing thin sheets of lead as an absorber between the water targets and the scintillation detector tanks. By measuring the reduction in counting rate produced by the lead, we could check the energy of the gamma rays in the first pulse. They were found to be the two simultaneous gamma rays produced when a positron-electron pair combines (or "annihilates," in the vernacular).

Evidence that the second pulse pair was due to the capture of a neutron by cadmium, and that the neutron had appeared in the detector simultaneously with the positron.—Again, we had two checks of this. We varied the amount of cadmium salt in the water targets and observed the varying times for observation of the second pulse following the first. These checked with the same data when a known neutron source was placed near the detector and neutron capture times measured. These capture time curves had already been run on computers at Los Alamos for different cadmium concentrations. These also agreed. The second check was the total pulse amplitude spectrum. This agreed with that obtained with known neutron sources. The pulses were due to neutrons. The capture time curves also demonstrated that the neutron had appeared with the positron, for it was the interval between the two that was measured, and this interval would not have checked had this not been so. Three different runs were made with different cadmium concentrations.

Dependence of the signal rate on the number of protons in the target.—For this check, we reduced the amount of hydrogen in the target to half, but did not reduce the amount of water. This was done by replacing the ordinary water with a mixture of 50 percent ordinary (light) water and 50 percent heavy water. Thus, 50 percent of the hydrogen had been replaced by deuterium, which has a comparatively very low cross section for antineutrinos compared with hydrogen. The signal rate fell when this was done as expected. This checked another point at the same time. By putting deuterium into the detector, we were sensitizing it to the effects of gamma rays and neutrons. Such backgrounds can easily break up a deuteron and mock up an antineutrino signal. Therefore, if the gamma ray and neutron backgrounds were fooling us before, the signal rate should have *increased* now rather than decreased as it was observed to do.

If we were seeing antineutrinos from the reactor, we should not be able to reduce their intensity on the detector by putting absorbers around it. If, on the other hand, we were seeing only gamma rays and neutrons, it should be easy to change the rate with absorber.— This simple experiment, however, took some time to devise, for a considerable amount of material was needed to stack around the detector to form our shield. This amount of *anything* looked very expensive to us. We first thought of wooden planks and timbers. The cutting and fitting problem was too great for wood. We considered water, but the tanks required would have been expensive and very large.

As we were in South Carolina in the summer, an obvious suggestion was a great pile of watermelons. We doubted that they would have survived long enought in a sweet condition. Another suggestion was sacks of hominy grits. An enterprising member of the group actually located a warehouseman in Augusta, Ga., who was willing to lend us the requisite amount. We feared, however, that he would be reluctant to take them back when he learned that they had been placed very close to the Nation's largest nuclear reactor! The native resources of the South did come to our rescue, however.

We used sawdust. Obtained free from a sawmill in Aiken, S.C., and bagged as it came from the chute, we hauled it in great truckloads to the reactor site. The sawdust was too light for our liking, so we piled it into a small mountain and squirted it with a firehose for several days. Drained and stacked around our detector, it provided a fine shield. In recognition of the Southern hospitality which we were enjoying all this time, we also incorporated hominy grits into the shield—a pound of it. (See pl. 3, fig. 2.)

Tested with neutron and gamma ray sources carried around it and placed in various places in it, the shield was fine. It reduced such artificial signals by large amounts. *But it made no difference to our reactor signal.*

This test, alone, was sufficient to demonstrate that we were observing antineutrinos from the reactor.

QUOD ERAT DEMONSTRANDUM

We were done. For a few days, we enjoyed the knowledge privately that Pauli had guessed correctly as we prepared a report to this effect for publication in the literature and for a summer meeting of the American Physical Society at Yale. The experience of knowing a fact new to mankind and knowing it for awhile all alone is an unforgettable one. The neutrino existed as an objective, demonstrable fact of nature. The great laws of conservation stood firm. And our small group had had the privilege of sharing in the work that made them so.

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Fracture of Solids[1]

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[With 4 plates]

The failure of a solid by fracture is an experience common to all, whether it be the breaking of a cup, the shattering of a car windscreen, or the event leading to disaster with an aircraft. The nature of the initiation, subsequent path, and speed of development of fracture often appear unpredictable. The result of fracture is frequently catastrophic. It is this aspect of finality which creates the greatest problems for the engineer who at present only overcomes them by clever design and the use of large safety factors.

It would, of course, be difficult and undesirable to avoid using brittle solids since they combine so many useful properties with their brittleness. Glass as the prime example of a brittle solid has, in one or other of its forms, high hardness, good resistance to chemical reaction and thermal shock as well as its most valuable of properties, transparency. Further, one of the many modern requirements is for solids which remain strong at high temperatures. Above about 1,000° C. the solids which still retain some degree of strength are frequently those that exhibit brittleness at room temperature.

Fracture is, however, not only a calamity to be avoided; it is frequently the best way of dividing a solid. The energy required to cleave a diamond or split a log is far lower than that needed by any sawing process. The surfaces of cleaved materials are frequently smooth and plane; properties which have many scientific uses besides their importance in jewel stones.

TYPES OF FRACTURE

If a solid is pulled hard enough it will eventually fracture. On the atomic scale this is the stage where the binding forces between the atoms are finally overcome by the tensile stress we have applied. The

[1] Reprinted by permission from *The Times Science Review* (London), No. 51, Spring 1964.

process of separation can take a variety of forms: A rubbery material elongates enormously before tearing; metals often deform before breaking (ductile fracture); glass fractures with little previous deformation (brittle behavior); and crystals frequently cleave along definite crystallographic planes. It is important to realize that a given material does not fall into a specific class regardless of the conditions in which it is used. A rubbery solid, for example, if taken to a low enough temperature, will fracture in a brittle fashion, and metals show similar temperature transitions from ductile to brittle behavior. A factor as important as temperature is the time taken in applying the stress to the material. If the stress is applied in a short time (i.e., a high rate of strain) the effect is analogous to that of decreasing the temperature of the body. The variation of behavior with strain rate is readily apparent with polymers such as Perspex. If a steel ball is pressed slowly against the surface the material deforms to give a permanent depression. If, however, the ball is allowed to fall from a height of a few inches, a circular ring fracture similar to those produced on glass is formed.

STRENGTH OF SOLIDS

Theoretical calculations of strength are usually based on the way that the forces between the atoms vary with separation. Usually the maximum force occurs when the separation between the atoms has been increased by 10 to 20 percent, or in other words, the theoretical strengths of solids lie between $E/5$ and $E/10$, where E is the Young's modulus of the solid. However, one of the more striking features about the strength of solids is the divergence between practical measured strengths and theoretical estimates: This divergence is greatest with brittle solids. Calculations on glass, for example, predict strengths as high as 2 million p.s.i., but plate glass has usually a strength only about one-hundredth of this and even glass in fiber form rarely exceeds one-tenth of the theoretical estimate.

A possible explanation for the low practical strengths was put forward in 1920 by A. A. Griffith, who suggested that microcracks on the surface and in the bulk of a solid could cause loss of strength. A useful analogy here is to imagine the cracks acting as levers to separate the atoms, the cracks becoming more effective the longer their lengths. Griffith, in experiments on glass, was able to show that the strength was in fact related to the depths of cracks which he artificially added to the glass.

The size of the microcracks sufficient to explain a practical strength for glass of 20,000 p.s.i. when its theoretical strength is 100 times higher turns out to be very small; cracks of length 1 or 2 microns (10^{-4}cm.) and widths of a few ångströms ($1Å=10^{-8}$cm.) are sufficient. It is not surprising, therefore, that even with modern electron microscopes

these microcracks are not easily observable. However, since 1920, decoration and etching techniques coupled with fracture experiments have built up a considerable body of evidence which largely substantiates the idea of microcracks. Other sources of weakness can also occur such as inclusions, voids, notches, and growth steps. All of these can act so as to increase the stress concentration at a point in the solid.

Crystalline materials (and this includes metallic crystals) may or may not contain microcracks initially, but they will usually contain defects of structure (dislocations) which will allow the planes of atoms to slide relative to each other without separation (plastic deformation). If the movement of the dislocations is blocked (this could be caused by the inclusion of a foreign particle) the dislocations build up causing a high-stress concentration with the possible formation of a microcrack. This crack could then initiate bulk fracture.

Materials without defects, such as carefully produced whiskers or fibers, exhibit high strengths approaching the theoretical values. This tends to confirm the importance of defects and indicates a possible, albeit difficult, way of obtaining high-strength solids.

TRANSMISSION OF STRESS

When a stress is applied to a body the disturbance is not experienced instantaneously throughout the whole body, but is transmitted by stress waves which travel with a definite velocity. The effect is very similar to that when ripples traverse the surface of a pond. In a solid whose properties are independent of direction, a disturbance travels through the body of the solid in two waves—a longitudinal (dilatational) wave in which the particle motions are in the direction of propagation, and transverse (distortional waves in which the particle motions normal to the wave front. The velocities of the wave depend on the elastic constants of the solid. These constants are themselves related to the elastic moduli (i.e., ratio of stress to strain produced). For glass, the longitudinal and transverse wave velocities are about 18,000 and 11,000 feet per second respectively, but for diamond, a material with very high elastic constants, the velocities are higher, having values of about 60,000 and 40,000 feet per second. Physically, the more rigid the atomic structure the faster the waves pass and vice versa.

Plate 1, fig. 1, shows pictures taken from a sequence of high-speed photographs of stress waves propagating in a Perspex specimen of dimensions 2 in.$\times$2 in.$\times$$\frac{3}{32}$ in. The waves were initiated by the detonation of a small charge of explosive at the midpoint of the top edge, and were made visible by the insertion of crossed polaroids into the optical system of the camera. Both waves are seen; the velocity of the fastest wave, the longitudinal, is about twice that of the transverse waves. When the waves reach the boundaries of the Perspex they

reflect and return through the block. This reflection always causes a change of phase and the longitudinal wave, for example, which passes out as a compression returns as a wave of tension. In thin plates of brittle material this effect can lead to failure causing a scab of material to become detached from the rear surface. The brittle solid fails in this manner since although it is strong in compression it is comparatively weak in tension. Instances of this so-called "scabbing" fracture were frequent in the last war when thin sheets of armor plate were struck by fast projectiles. Reinforcement by two waves, of either the same or different type, can also lead to localized fracture.

On the surface of a solid a third type of wave, the Rayleigh Surface wave, is developed. This wave travels at a velocity about 90 percent of the transverse wave. Since it exists only in a thin layer at the surface it loses energy in two dimensions, whereas the body waves do so in three. When transmitted over large distances this wave retains its intensity to a greater degree and is usually the main component of the disturbance from earthquakes. As will be seen below it is also important in explaining certain fracture phenomena.

MODE OF FRACTURE

The way in which the stress is applied to a solid greatly influences the final form of fracture. Starting at the one extreme of "static" loading this can perhaps best be represented by the example of a steel ball pressed with increasing force against the surface of a solid. With a brittle solid such as glass, the first form of failure is the formation of a "ring" crack which closely follows the edge of the contact area where the maximum tensile forces exist. The fracture usually starts at one point and then travels round, keeping at right angles to the maximum tensile stress, until the full circle is complete. The point of initiation may be slightly away from the contact area since it will depend on the location of the microcrack which gives the greatest stress concentration. If the stress is increased still further a second ring crack forms while the initial fracture develops into the solid forming a conical surface of fracture. Plate 1, fig. 2, shows this stage; the faint circular bands around the ring cracks are interference fringes formed in the gap between the fracture planes. In thin glass the fracture may reach the back surface giving a perfect cone of material. The cone angle is usually about 140°. (This form of failure is not to be confused with the scabbing failure mentioned briefly above in connection with stress waves.) Thin glass will also bend causing large tensile forces at the rear surface which result in long radial fractures growing from a point opposite the loaded area.

If the steel ball impacts against the glass stress waves have to be considered. At relatively low impact velocities the general appearance of the fracture does not greatly alter from the static case except that

the fracturing is more severe. The reason for this is that at low impact velocities the time of impact is relatively long and the stress waves, with their high velocity, have time to distribute information about the stress to all parts of the body during the impact time. Since the stress distribution quickly approaches that of the static case, the pattern of fracture for a low velocity impact is similar to that for static indentation. An example of this is window glass broken by a stone; the long radial fractures and the displaced cone of glass are the main features of the impact.

For very high impact velocities the duration of the impact becomes short compared with the time taken by the stress waves to pass through the body. Thus a point in the solid no longer receives a long train of stress waves which gradually build up the stress, but rather a concentrated pulse of stress of short duration. Very intense pulses lasting only 1 or 2 millionths of a second can be produced by a variety of methods, one of which is the detonation of a small quantity of explosive on the surface of a solid, or, as has been shown recently at Cambridge, when a jet of liquid strikes a solid at high velocity. (This result has practical significance when aircraft pass through rain.) An example of the fracturing caused by the impact of a cylinder of liquid water of diameter 3 mm. at 2,400 feet per second on plate glass is shown in plate 2, fig. 1. The diameter of the large ring fracture corresponds closely with the size of the head of the cylindrical jet. This ring fracture and central area closely resemble the static case illustrated in plate 1, fig. 2, except that the main ring crack is made up of several fractures rather than one continuous crack. The additional features are the short circumferential fractures. These are entirely of stress wave origin, and are formed when the sharp pulse reaches a microcrack capable of giving a stress concentration sufficient for fracture. The fractures remain short and develop as separate events since the stress waves are themselves of short duration. The stress wave which causes these particular fractures is the Rayleigh Surface wave. Their formation is illustrated in plate 2, fig. 2. The pictures, separated by only 2 microseconds, show a lead slug impacting against the top edge of a 3 in. by 3 in. by ¼ in. glass specimen at about 600 feet per second. The point at which fresh fractures appear moves out from the center at the Rayleigh wave velocity of approximately 10,000 feet per second.

When thin plates of glass are loaded by intense short duration pulses extra "bands" of fracture occur as seen in Plate 3, fig. 1. This shows the result of the impact of a cylinder of water at a velocity of approximately 4,000 feet per second on ½-inch-thick glass. The circular bands of fracture are again of stress wave origin, and occur only on the front surface. They are formed when the Rayleigh Surface wave is reinforced by tensile components from the stress waves reflected at the back surface of the glass. Similar bands have been produced on hard

polymers and certain crystalline solids. High-speed photographic records show that the formation of the bands is complete before the plate specimen starts to bend and that only at a later time do the long radial fractures produced by the bending start to develop.

FRACTURE VELOCITY

Once a fracture is initiated the question arises as to how fast it can travel. The answer appears to be that a fracture can have any velocity up to a certain maximum. It is reasonable that a maximum velocity exists since it would not be expected that a fracture velocity would exceed stress wave velocities, since in the one case a rupture of atomic bands occurs and in the other merely a transmission of stress.

The measurement of fracture velocities is usually achieved by the use of high-speed photography or ultrasonic techniques, although markings on the fracture surfaces often give extra information. Examples of these markings include faint lines called "rib" marks which are formed when a fracture pauses, and other lines ("river" patterns) which denote the direction of travel of the fracture for each part of the surface. These "river" patterns occur on glasses, and both metallic and nonmetallic crystals and are formed when the fracture advances simultaneously on slightly different levels. The most important markings for velocity determinations are Wallner lines (named after H. Wallner who first explained them) and an example is shown in plate 3, fig. 2. These were photographed on the fracture surface of a glass plate. The lines are formed by the interaction of the fracture front with transverse stress pulses started when the fracture passes through an imperfection, usually at the edge of the specimen. If the fracture origin is known and also the transverse wave velocity for the solid, the fracture velocity can be determined. This idea has recently been extended and an ultrasonic beam of waves of frequency about 5 megacycles per second is passed through the solid as the fracture advances. The resultant fracture surface shows a series of fine ripples, and the spacing of these, since the time interval is accurately known, gives a direct measure of the fracture velocity.

High-speed photography is a technique which can measure fracture velocities accurately (to about 1 percent) provided the camera is capable of giving accurate synchronization and framing rates in excess of 10^6 per second (i.e., the order of 1 microsecond between pictures). A sequence showing the fracture of a toughened glass specimen is given in plate 4, fig. 1. This is the type of glass frequently used in car windowscreens. The glass is about five times stronger than plate glass, and is made from plate glass by a heat treatment process which puts a thin outer layer into compression. However, the treatment leaves the inner layers in tension and if a crack grows through the outer layer the fracture propagates catastrophically. It is clear

TABLE 1.—*Fracture and Stress Wave Velocities* (*In feet per second*)

Material F	Fracture velocity (V)	Longitudinal wave velocity (C_1)	Transverse wave velocity (C_2)	V_F/C_1
Soda glass	5, 000	18, 000	11, 000	0. 28
Fused silica	7, 000	19, 500	12, 500	0. 36
Sapphire	14, 500	36, 000	21, 000	0. 4
Diamond	24, 000	60, 000	40, 000	0. 4

from the picture that the fractures all travel at the same velocity. The change of appearance in the fracture pattern after frame 8 (fourth in row 2) is caused by the interaction of the reflected longitudinal pulse, now a tension, with the advancing front.

Recent fracture velocity and stress wave velocity measurements made at Cambridge from sequences such as in plate 1, fig. 1; plate 2, fig. 2; and plate 4, fig. 2, are shown in table 1 above. The fracture velocities are all approximately one-third of the longitudinal stress wave velocity. Fracture velocities in metals are usually a lower fraction of the stress wave velocities. This is mainly because much of the fracture energy is lost in doing plastic work. The smaller value of the ratio for glass (0.28 as compared with 0.4 for sapphire and diamond) may also be significant in showing that glass itself does not behave in a completely brittle fashion. (Indentation experiments have also indicated this.)

REMOVAL OF SURFACE DEFECTS

It appears that the key to the strength of solids lies in the existence of microcracks and other imperfections. Once these are removed higher strengths ensue. Several materials have already been produced in fiber and whisker form with high strengths. Experiment shows that glass has most of its flaws located at the surface and is therefore amenable to surface treatments such as toughening, ion exchange (in which the sodium atoms at the surface are replaced by larger ones, thus putting the surface layers into compression), and etching. In the etching process hydrofluoric acid acts partly by removing the flawed layer and partly by rounding off the flaw tips. The effect of removing a few microns (10^{-4} cm.) of glass, and greatly improving the strength, is illustrated by the impact mark in plate 4, fig. 2, in which the lower half only of the specimen was etched. Impact was by a liquid jet on the dividing line between the treated and untreated regions (see also plate 2, fig. 1). Improvements of strength by etching of up to 500,000 p.s.i. have so far been reported. Materials such as hard polymers and ceramics have flaws distributed throughout the bulk, so a surface treatment alone does not have such a marked effect (their initial practical strengths may, of course, be higher).

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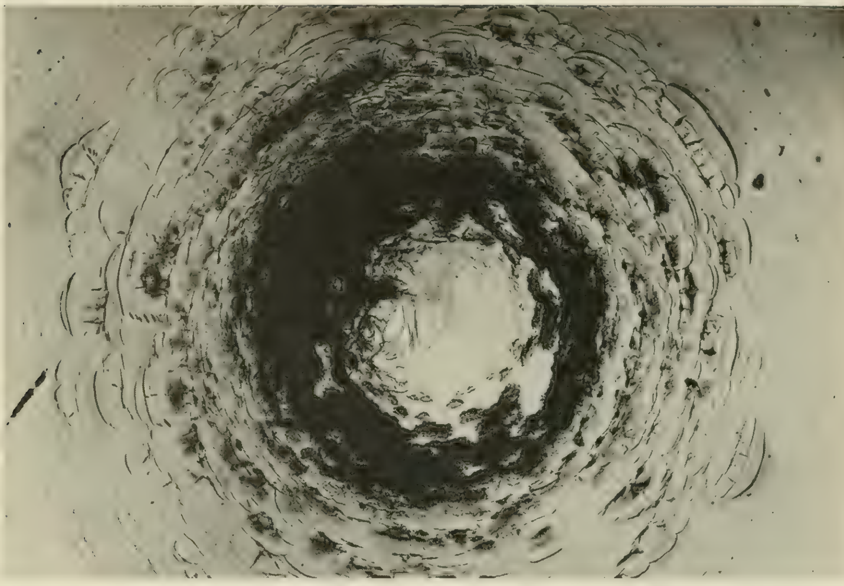
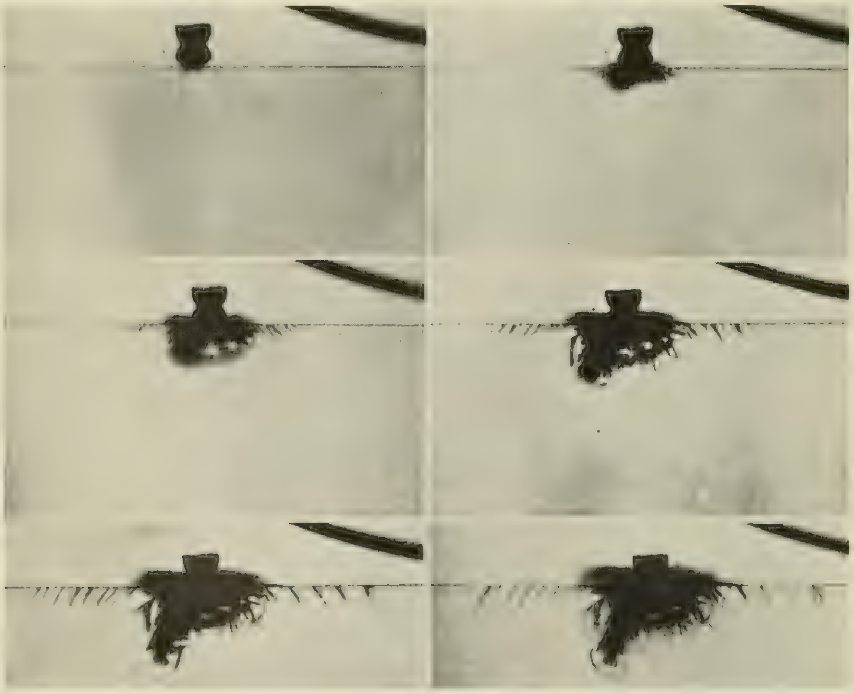
The fact that fractures propagate less easily in materials in which some plastic work occurs as the fracture advances may prove useful. Indications are that reinforced solids can be devised which, while retaining many of the good properties that brittle solids have, will inhibit fracture growth of catastrophic nature. Certainly a large amount of information about the strength properties of solids has been assembled in the comparatively short time since the original paper by Griffith. In the last few years understanding of the cause of fracture and the mechanism of its propagation has advanced considerably. It is reasonable to expect that in the near future new and exciting materials will be developed.

1. High-speed pictures, each separated by 3 microseconds, of stress waves passing through a 2in. x 2in. x $^{3}/_{32}$in. Perspex block. The waves were initiated by an explosive charge detonated at the mid-point of the top edge. The longitudinal wave travels at about twice the velocity of the transverse. Reflection takes place first at the sides and afterward at the bottom surface of the specimen.

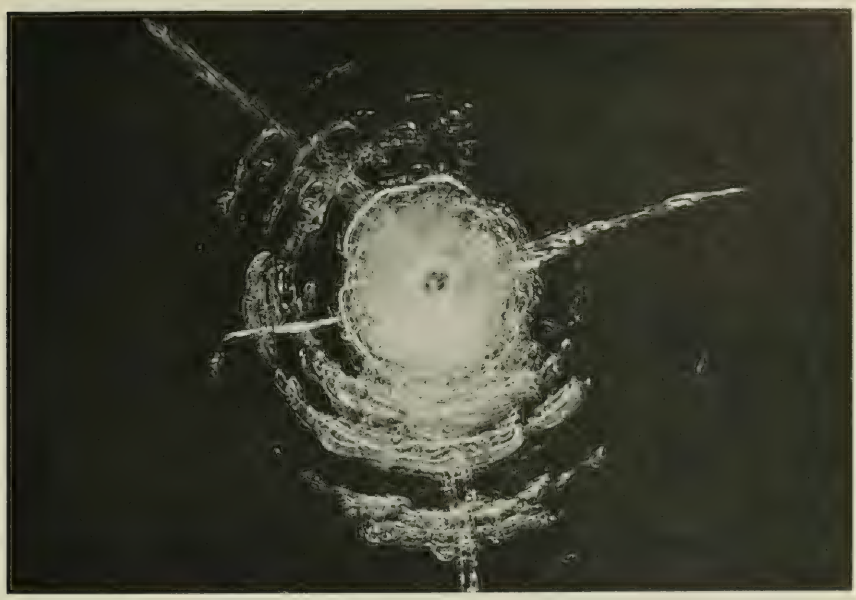
2. A ring fracture produced by pressing a $\frac{1}{2}$ inch diameter steel ball against plate glass. (Magnification $\times$ 23.)



1. Fractures produced on glass by the impact of a liquid cylinder at 2,400 feet per second. This impact gives a short but intense pulse of pressure which initiates the many short circumferential cracks. These cracks are not found under static or slow impact conditions. (Magnification $\times$ 13.5.)

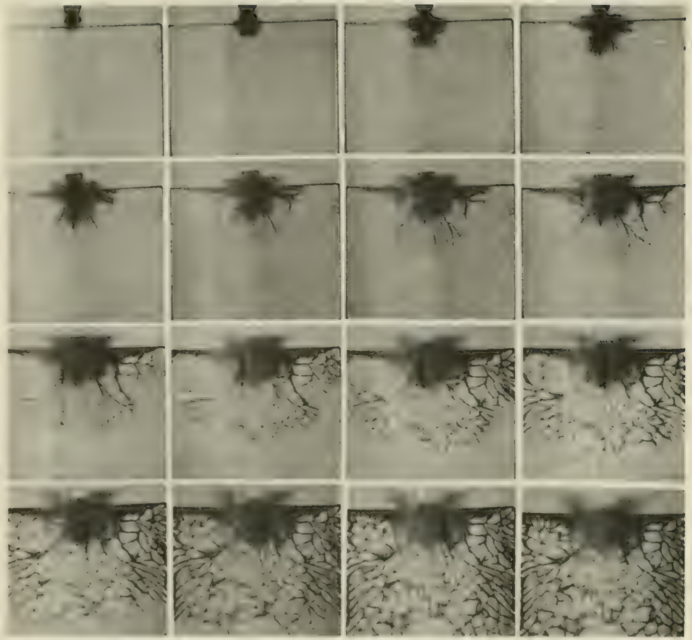


2. The short fractures along the top edge of the glass plate are initiated by the Rayleigh Surface wave caused by the impact of the lead slug. The interval between frames is 2 microseconds.



1. Fractures produced on the surface of a ½ inch thick glass plate by the impact of a liquid cylinder at 4,000 feet per second. The "bands" of fracture are caused by the reinforcement of the Rayleigh Surface wave by stress waves reflected from the rear surface of the plate. (Magnification × 1.04.)

2. Wallner lines found on the fracture surface of a glass plate. Since they are formed by the interference of the fracture front with transverse stress waves it is possible to determine the fracture velocity. (Magnification × 6.5.)



1. Fracture propagation in a 2in. x 2in. x $\frac{1}{4}$ in. specimen of toughened glass. The interval between pictures is 2 microseconds. Once the fracture process starts it proceeds catastrophically. The fractures propagate at a velocity of 4,900 feet per second. The marked change in pattern after frame 8 (at the right of the second row) is caused by interaction with the reflected longitudinal pulse.

2. The lower half of the specimen was etched, with the removal of 8×10^{-4} cm. of glass, before impact by a liquid jet on the dividing line between the regions. Removal of this thickness increased the strength of the glass about 8 times. (Magnification $\times$ 10.)

Man-Made[1] Diamonds—A Progress Report[2]

By C. G. SUITS

Vice President and Director of Research
General Electric Company

[With 4 plates]

THIS IS, FIRST of all, a story about carbon, the most aggressively gregarious element of the periodic table. Carbon, compounded, is so versatile in nature that the major branches of chemistry are determined entirely by the presence or absence of this element. Carbon, by itself in crystalline form, offers another distinctive dichotomy: It can be slippery, messy graphite worth a few pennies a pound; and, at the other extreme, it can be magnificent diamond, nature's hardest and most glamorous substance, sometimes valued at millions of dollars an ounce.

Converting a plentiful, cheap, and even worthless material into something rare and valuable was once thought to be a peculiar preoccupation of alchemists. If a play on words will be forgiven, we might say that this is now a worthy *occupation* for *all chemists*, all physicists, and all metallurgists—at least in industrial laboratories.

There have, of course, been some spectacular successes in this effort. Witness, as examples, the conversion of nearly worthless natural silicon found in sand to the highly valuable semiconductor-grade silicon on which a large segment of the semiconductor industry is based; or the conversion of cheap hydrocarbons—residues from coal, oil, and gas—to monomers and then to polymers of great utility and economic value. The planning, execution, and fruition of a successful venture in modern alchemy are among the great satisfactions of today's scientists, technologists, and engineers.

It is not surprising that the history of science is replete with attempts to convert base carbon to noble diamond, and that the story is interlaced with claims and disclaimers, mystery and jealousy, suspense and intrigue.

[1] Trademark of General Electric Co.

[2] Reprinted by permission from *American Scientist*, vol. 52, 1964.

The task itself is conceptually simple. Graphite is composed of carbon atoms, tightly bound in planes, with comparatively weak atomic forces holding the planes together; the flaky character of graphite is the macroscopic evidence of this atomic structure. Diamond is composed of precisely the same carbon atoms squeezed together to achieve substantially uniform inter-atom distances throughout the lattice. Thus, the diamond lattice is a neat packing configuration which gives each atom a tight hold on each of the four atoms arrayed around it. In other words, to turn graphite into diamond, all one must do is press it into the more compact atomic arrangement of diamond, as is shown in plate 1, fig. 1. What could be simpler?

But, alas, as countless investigators over the years have learned to their agonizing dismay, Mother Nature did not intend her own achievement—probably performed at mysterious, unexplored depths far beneath the surface of the earth—to be easily accomplished by man. The late Professor Percy Bridgman of Harvard, a Nobel laureate for his work on high-pressure phenomena, put it succinctly. "Graphite," he said, "is nature's strongest spring."

Or, in the less grammatical phrase of one of our laboratory associates, it might be said that "it is easy to squeeze carbon atoms together, but very difficult to keep them squz."

Professor Bridgman spent many years trying to make diamonds during the 1920's, 1930's, and 1940's, and found serious natural roadblocks at every step on this road. The most serious roadblocks were: (1) An understanding of the diamond-making process, and (2) the requirement of high pressure and high temperature simultaneously, both held for an appreciable interval of time. Bridgman produced pressures which were much greater than required, but the "spring" relaxed to graphite when the pressure was reduced. On the basis of what he learned, Bridgman concluded that all previous claims to success in diamond-making were based on wishful thinking and not scientific proof.

In 1951, my associates [3] and I decided to launch a new, all-out assault on this problem. We resolved to delve into the process whereby diamond might be made, using not only new techniques for attaining fantastically high pressures, but also for attaining the simultaneous high temperatures that would be required to "latch" this spring: thus, to form diamond from graphite.

Let us now discuss three aspects of the diamond problem in turn: the pressure, the temperature, and the chemistry—and then add a comment about a fourth factor—time.

Using the strongest available materials, unique prestressing techniques, and geometrically complex designs which permit the microflow

[3] A group led by A. J. Nerad and including Drs. F. P. Bundy, H. T. Hall, H. M. Strong, R. H. Wentorf, Jr., and H. P. Bovenkerk.

of pistons and cylinders at extremes of pressure, the project to which we have referred has developed equipment capable of withstanding pressures of up to 3,000,000 pounds per square inch. This is 200,000 times atmospheric pressure, or, as the scientists put it, 200 kilobars. It is the pressure that would be found some 330 miles beneath the earth's surface. Or, expressed another way, it represents the pressure of a column of mercury 100 miles high, a rather substantial barometer reading. These astounding pressures, however, are not a record. Bridgman attained much higher pressures by far simpler means. The new progress, in apparatus, came from a chamber design that permitted the simultaneous attainment of high pressure *and* high temperature.

In terms of temperature, we have consistently referred to "5000 degrees." In the early days of diamond-making we meant Fahrenheit, and 5000° F. is still the temperature which can be held for "a long time"—hours if need be. More recently, temperatures of 5000° K.—about 9000° F.—have been achieved for periods of a few hundredths of a second in our superpressure chambers. This is nearly the temperature of the sun's surface.

The development of these pressure chambers has been described in detail on another occasion.[4] The present form of the high pressure "belt" is shown in diagrammatic view in figure 1.

Chemistry was at least as important to the initial achievement of diamond-making as the temperature-pressure combination. It has been found that certain metals, which are molten in the process environment, act as catalysts and greatly enhance the rate of the required change in the lattice arrangement. The net result of catalysis is a higher yield at a higher rate, at significantly reduced temperatures and pressures. Thanks to pressure, temperature, and chemistry, the graphite "stayed squz" and emerged as diamond.

As we have seen, it is possible in superpressure chambers to hold the chamber conditions for long periods of time and thus to achieve a steady state for reactions under study. A temperature limit of about 3000° K. is set for such steady state use primarily by the available material properties, particularly the melting points of ceramic bodies. Under steady state conditions, say, 1.5 million pounds per square inch and 1500° K., the diamond stable region of the carbon phase diagram is attained, but the diamond transition was not originally observed except in the presence of the catalyst. Francis Bundy showed, in static apparatus, by extending the temperature to 5000° K. for transient excursions, that the *direct* conversion of graphite to diamond—that is, without catalyst action—takes place. This is illustrated strikingly

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[4] C. G. Suits, "The Synthesis of Diamond—A Case History in Modern Science," read November 3, 1960, before the American Chemical Society, General Electric Research Laboratory Report No. 60-GP-189.

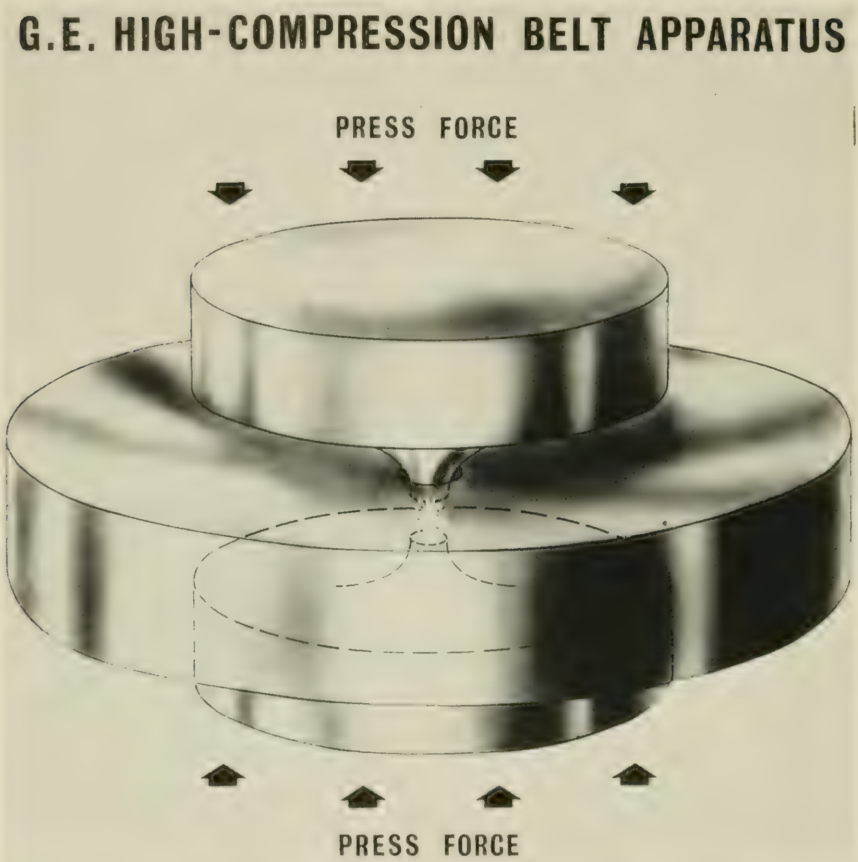


FIGURE 1.—Present form of the high pressure "belt."

by the photograph (pl. 1, fig. 2) of a bar of graphite which has been squeezed to diamond in its central section by these extreme transient conditions. (The density of graphite is 2.25; that of diamond, 3.52.) Still more recently, Bundy and Robert H. Wentorf, Jr., have detected direct conversions at the upper end of the steady state temperature-pressure regime. And, the answer to the question of *time* is one of nature's bounties: the time is "short"—a matter of minutes or seconds, once reaction conditions have been attained.

The announcement that diamonds had been made at the General Electric Research Laboratory appeared in February 1955. To be honest, it should be noted that the diamonds made up to that time were small, as shown in plate 2, fig. 1. Although they could be seen with the naked eye, it was better to use a microscope, and it was important not to sneeze, for that might have done away with the entire world supply at that time.

The initial reaction to this announcement was, nevertheless, spectacular. For example, on the stock market, the total value of General Electric stock increased that day by more than $300 million. Although this was an important discovery, the market reaction was in this case, as in other cases that might be mentioned, more emotional than analytical. To justify a $300-million increase in market price on the basis of a diamond business, even with very favorable profit ratios, would require an annual sales volume greater than $3 billion, which was the approximate level of General Electric total sales at that time. The total worldwide sales of the diamond industry at that time were about $\frac{1}{10}$ of this level. After a few days, during which such calculations were undoubtedly performed, the price of General Electric stock "recovered" to nearly its former level.

The announcement released in 1955 made it clear that Man-Made diamonds were small and were not of gem quality. One might jump to the conclusion that only diamond gems are really valuable. To put this question in proper perspective, one must bear in mind that the bulk of diamond production from all sources, worldwide, is in industrial grades with a total market value of about $60 million. The very much smaller physical volume of gem diamond sells at a very much larger unit price to achieve a worldwide sales level of about $300 million per annum.

A few points should be made concerning the value of diamond, the price of diamond, and some factors which determine both. Diamond has only one unique property—hardness—and this property is fundamental to its industrial use and its usefulness as a gem. However, hardness is a necessary but not a sufficient attribute of a crystal to be used as a gem. As a gem, diamond has other important properties such as a high refractive index and must have other additional qualities, such as size, color, and optical clarity. But, without its exceptional hardness, diamond would not be preeminent as a gem. A higher refractive index is available in other crystals, especially titania, and large clear crystals of many other minerals are readily available.

Many persons have had the experience of wearing a ruby or sapphire gem in a ring for a period of years. A careful examination of the stone will show definite evidence of wear. On a true hardness scale, however, as figure 2 shows, diamond is about five times harder than ruby and sapphire and it will accommodate the appreciable wear requirements of a gem stone. Thus, diamond is probably the only gem which can be used in an engagement ring which will survive the ideal marriage.

The same unique property—hardness—is the essence of diamond's industrial usefulness. This reduces in most cases to the ability, as in the case of a gem, to retain sharp corners under conditions of wear. The conditions of wear in industrial applications are, of course, much

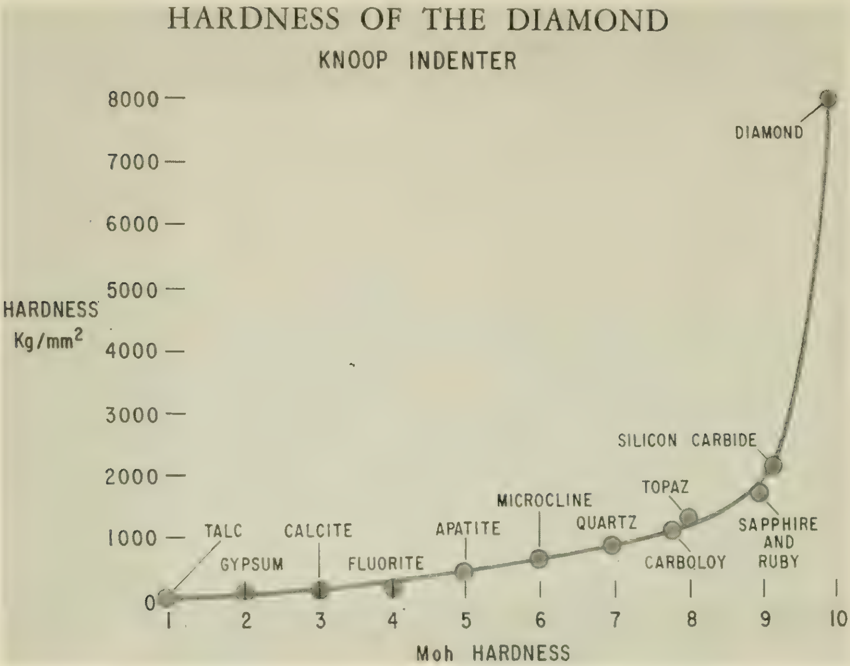


FIGURE 2.—Diamond is many times harder than ruby and sapphire.

more severe than in engagement ring service. A suitable diamond saw can be used to cut concrete, for example, which it does, much as a steel saw cuts wood. Even more important, diamond wheels are used to cut the hardest and strongest metals and alloys—like Carboloy cemented carbides—and the vital industrial usefulness of these carbides depends upon the availability of diamond for cutting these materials during manufacture.

Fortunately, diamonds do not have to be beautiful in order to be hard. The bulk of the diamonds dug from the earth are small, discolored, and not worth polishing, but their hardness is the same as diamond of gem quality. These poor cousins of the million-dollars-an-ounce gem stones are worth only a fraction of gem prices, which fraction, however, is still about $6,000 a pound based on a typical diamond grit price of $2.65 per carat.

Soon after the discovery of the laboratory diamond process, we had to face the question: "Can Man-Made diamonds be produced that are good enough and inexpensive enough to compete with natural diamond bort?"

The answer came in a remarkably short time. A team of scientists, engineers, and manufacturing experts joined forces to make these Man-Made diamonds a competitive industrial product, and—as plate 2, fig. 2, shows—this objective was achieved in less than 3 years.

With this final step, America acquired for the first time an independent source of industrial diamond, a material which is very important to the industrial economy, and which is absolutely vital in key defense industries. The assurance of a steady supply of industrial diamond has encouraged broader use of this exceptional material for new applications. And, surprisingly enough, the new Man-Made product has turned out to be better than natural diamond for many applications.

Man-Made diamonds are grown under controlled conditions, and remarkable control can be exercised over the properties of the tiny crystals. For some purposes it is desirable to produce friable crystals, so that fresh cutting surfaces will be exposed during use; such crystals can be grown. For other purposes—for example, metal-bonded circular saws—the ideal crystal would be an octahedron of the correct size: such crystals can be grown. This is an improvement on natural diamond because tiny crystals are not recovered from natural sources, and hence fine mesh-size, natural diamond is generally produced by crushing, which does not readily yield the desired crystal shape. Thus, nature's hardest substance is now subject to quality control, which has significantly enhanced its industrial usefulness.

A "diamond mine," in Detroit, part of the General Electric Co.'s Metallurgical Products Department, is now one of the largest single sources of industrial diamond in the world. The product is made reliably and at a price that is directly competitive with natural diamonds. The total production of diamonds from this mine to date is not properly measured in carats, but in tons.

Most industrial diamonds, including Man-Made diamonds now on the market, are very small: up to about half a millimeter in diameter and weighing only about a thousandth of a carat or less. However, diamonds in these small sizes in the form of abrasive grit fill a large portion of industrial needs. Meanwhile, considerably larger Man-Made diamonds—1 or 2 mm. long and of good quality—can be made.

Research continues toward the development of larger industrial stones, up to and including the carat-size diamonds required for oil-drill bits and wiredrawing dies. By growing the crystals in a multi-step process—adding a layer at a time—it has been possible in the laboratory to make diamonds weighing more than two carats (pl. 3). It must be noted, however, that these crystals are quite imperfect. They are not very strong because of inclusions, particularly between the layers, and because of internal strains in the crystal structure. They are definitely not the kind of clear, perfect stones suitable for polishing into something of interest to the ladies.

The scientific achievement of Man-Made diamond, and the commercial success of the product, have served to stimulate broad interest in high-pressure research at laboratories all over the world. Approximately 200 laboratories are now equipped for superpressure research,

and much new useful knowledge of nature's physical extremes is coming from this work.

Many of the exploratory efforts in superpressure incorporate so-called "dynamic" or explosive shock techniques in which very high temperatures and pressures up to a million atmospheres are obtained for very short periods of time, usually a few millionths of a second. Diamonds have been made by these processes. Alternatively, very high "static" pressures, such as 500 kilobars, together with high temperatures, may be attained at a sacrifice of reaction volume, and some interesting researches are being conducted by this method. Many new forms of matter are being explored at superpressures, and it is clear that the final chapters to the story of superpressure have not yet been written. One must expect exciting news from this source of scientific exploration for many years in the future.

The chart in figure 3 shows some of the capabilities of different approaches. The "belt" apparatus developed at the General Electric Research Laboratory, because of its unique combination of 200 kilobar pressures and 3000 to 5000° K. temperatures—plus workable pressure-chamber volumes—has thus far provided an excellent diamondmaking method as well as the research technique with greatest versatility. Superpressure research around the world is now concerned with such subjects as the determination of the elastic constants of various mate-

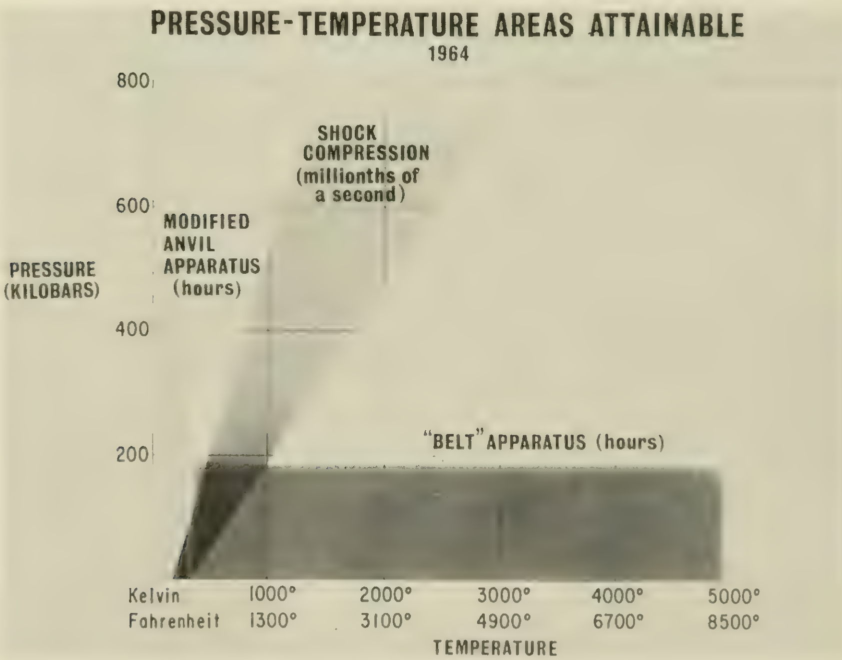
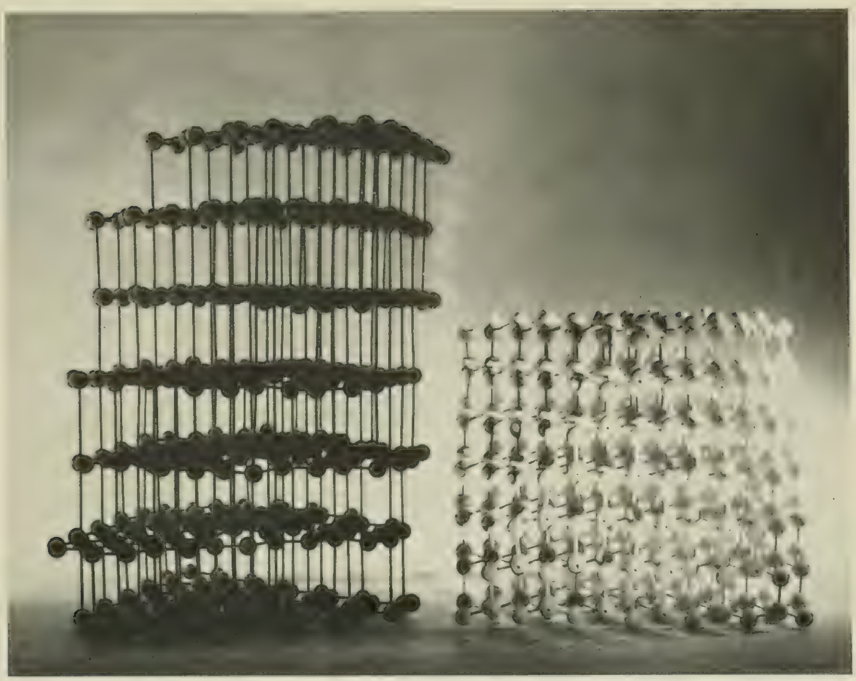


FIGURE 3.—Capabilities of different approaches.



1. Model of graphite lattice (left) and diamond lattice (right).

2. Bar of graphite squeezed to diamond in its central section.

1. Photomicrograph of early Man-Made diamonds (40 ×).

2. Collection of one-quarter million carats of Man-Made diamonds.

Man-Made diamonds weighing two carats (9 ×).

1. Borazon—a completely new material never found in nature (56 ×).

2. Face of natural diamond gem stone (right) scratched by a piece of Borazon.

rials, the properties of semiconductors at high pressure, nuclear magnetic resonance in solids and liquids under pressure, the determination of fixed points on the high-pressure scale, geochemical and geophysical studies, a variety of thermodynamic approaches to the study of activated processes under high pressure, and scores of other seemingly esoteric but inherently valuable research objectives.

In more down-to-earth language, it might be said that—obviously—it is possible to put many materials other than carbon into these chambers and subject them to high pressure and high temperature for long periods of time. Such possibilities provide a virtually infinite challenge for the research scientist.

One of the first results of this kind of exploration was a new form of boron nitride. Boron nitride, in its common form, has a structure very similar to graphite, with boron and nitrogen replacing carbon in the lattice. It is a slippery material so much like graphite in mechanical properties that it is often called "white graphite." Boron nitride was sufficiently intriguing to prompt Wentorf at our laboratory to try superpressure techniques on this material.

The result was spectacular: A completely new material never found in nature (pl. 4, fig 1). "Borazon," as it was named, is in the same range of hardness as diamond. As the photograph (pl. 4, fig. 2) shows, it is the only material other than diamond that has ever been able to scratch diamond. Because borazon is more oxidation-resistant than diamond, we believe it will eventually have important industrial applications. In addition to borazon, more than 20 new forms of matter have been created through superpressure research in the one program with which I am most familiar. Principally, these are chemical compounds, although in some cases they are single elements converted into new crystalline arrangements. At present there is considerable scientific excitement in the laboratory concerning evidence which points to the possibility of a completely new crystal form of carbon. However, this work is still incomplete, and requires confirmation. In the case of both germanium and silicon, we and other workers in the field have identified some new high-density forms substantially different from the crystal structure which helps give these materials their unique value as semiconductors.

But this was to be mainly a story about carbon, that many-faceted element which is so dominant in science and life. What is the future for carbon as we continue to heat it and squeeze it and catalyze it?

We are gradually learning how to make larger and larger diamond crystals—how to control the nucleation of crystal growth and achieve bigger single crystals with fewer occlusions and imperfections. We are learning how to keep unwanted atoms out of the carbon structure, and it seems reasonable to hope that stronger, more perfect crystals will result. Finally, we like to look at the phase diagram for carbon

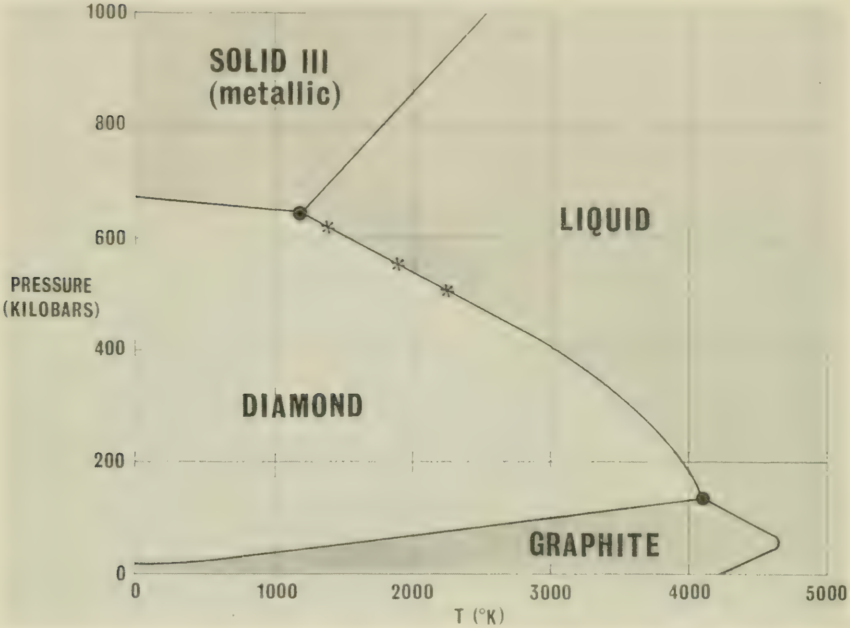


Figure 4.—Phase diagram for carbon.

in figure 4 and dream of the time when we can attain the presently unattainable areas of temperature and pressure. Perhaps carbon will assume a new form harder than diamond. In any event, crystallographers can conceive of atomic arrangements which might put carbon atoms even closer together—and more firmly bound—than they are in diamond. The result might be—who knows!

How Do Microbes "Fix" Nitrogen From the Air?[1]

By D. J. D. Nicholas

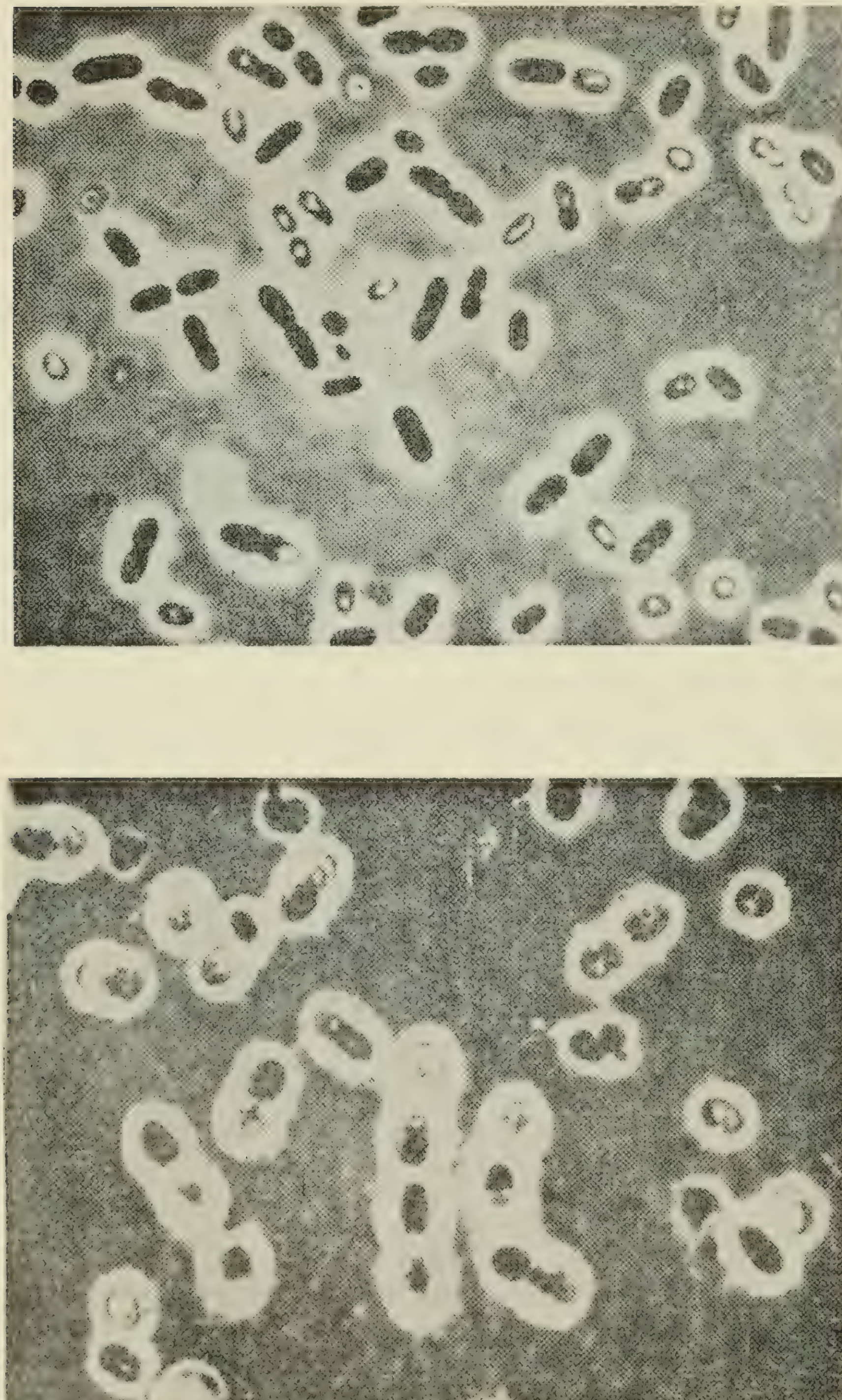
Long Ashton Research Station, University of Bristol

All living things contain nitrogen compounds and all agriculture depends upon the presence of combined nitrogen in the soil. A supply of nitrogen compounds on Earth has been built up over a period of millions of years by physical forces, notably lightning, whereby nitric acid is formed in thunderstorms. The bulk of the combined nitrogen comes, however, from the remarkable ability to convert the nitrogen gas of the air into protein, possessed by a few species of free-living microorganisms that inhabit soils and seas, and by others that live in interdependence (symbiosis) with the roots or leaves of plants. These microorganisms "fix" about 100 million tons of nitrogen a year and play a vital part in the nitrogen cycle in nature (fig. 2), without which all plant, animal, and human life would come to a halt.

The relatively few microorganisms so far known to fix atmospheric nitrogen gas are listed in table 1. Of the free-living bacteria, only *Azotobacter* requires oxygen for growth (fig. 1). The majority, however, are "anaerobes," inhibited by oxygen and thriving only when it is absent. Other types of nitrogen-fixing bacteria also ultilize carbon dioxide from the air, however, in the process of photosynthesis, and some blue-green algae perform this dual function of carbon dioxide and nitrogen fixation.

What of the microorganisms that fix nitrogen while living in symbiotic association with higher plants? The best known plants taking part in this process are probably the leguminous species, including the economic crops, clover, alfalfa, peas and beans, where various strains of rhizobia bacteria invade the roots, forming nodules. It is not widely known that about nine kinds of ordinary flowering plants (nonlegumes) also have root nodules in which nitrogen fixation takes place, such as alder in temperate zones and *Casuarina* and *Myrica* in warmer

[1] Reprinted by permission from *New Scientist* (No. 169), London, December 1963.



A. agilis. *A. chroococcum.*

FIGURE 1. *Azotobacter* phase-contrast micrographs (× 1757). (Courtesy H. L. Jensen.)

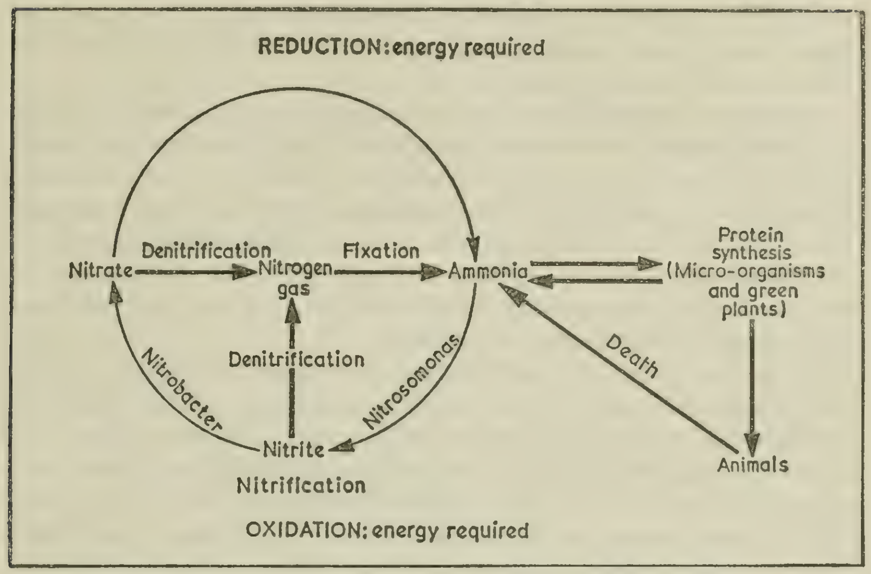


FIGURE 2.—Principal reactions in the nitrogen cycle in nature.

TABLE 1.—*Asymbiotic and symbiotic microorganisms which fix nitrogen gas*

Biological system	Type	Microorganism
Asymbiotic free-living microorganisms:		
Bacteria	Aerobe	*Azotobacter*
	Aerobe (Photosynthetic).	*Rhodospirillum rubrum, Chromatium, Chlorobium, Rhodomicrobium*
	Anaerobe	*Aerobacter, Bacillus polymyxa, Achromobacter*
Yeasts	Aerobe	*Rhodotorula*
Blue-green algae	Aerobe (Photosynthetic).	*Nostoc, Anabaena, Calothrix,* etc.
Symbiotic microorganisms in nodules of plants:		
Root nodules. Legumes, e.g., peas, beans, clover, alfalfa.		*Rhizobium*
Root nodules. Nonlegumes, e.g., alder, *Casuarina, Myrica.*		*Actinomycetes?*
Leaf nodules. *Psychotria bacteriophila.*		*Klebsiella*

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areas. The organisms responsible for nitrogen fixation in these nonleguminous plants have not been definitely identified but they are believed to be Actinomycetes.

An interesting association has been found recently between a nitrogen-fixing bacterium occurring in "leaf nodules" of a subtropical plant *Psychotria bacteriophila.* The bacterium, identified as a *Klebsiella*, is the first example of a symbiotic microorganism that will fix nitrogen when grown in the absence of its host. Another interesting feature is that this bacterium not only fixes nitrogen gas but is also involved in the synthesis of substances that promote growth in the host plant and are essential for its normal development.

Not all the examples given in table 1 have been thoroughly checked for their fixation abilities and it is still doubtful whether the yeast *Rhodotorula* is able to fix gaseous nitrogen. Claims have been put forward for other microorganisms either alone or in association with other organisms such as actinomycetes, yeasts, mycorhiza, and lichens, and for some unusual associations of bacteria with insects and goats. These reports of nitrogen fixation, however, have still to be confirmed.

Atmospheric nitrogen is relatively inert. The industrial synthesis of ammonia from nitrogen and hydrogen requires temperatures of about 500° C. and pressures above 350 atmospheres. The process consumes a great deal of energy—equivalent to 5 tons of coal per ton of nitrogen (see table 2). By contrast, microbial fixation works at ordinary temperatures and pressures.

Although the assimilation of carbon dioxide in photosynthesis in green plants has been resolved, largely through the brilliant work of Calvin and his associates at Berkeley, the equally important mechanism of nitrogen fixation is still relatively unexplored. Since the pioneer work carried out over 20 years ago by Virtanen and his colleagues in Helsinki, and by Burris and Wilson and their group at the University of Wisconsin, progress has, until recently, been slow. There were two main reasons. The first was the lack of success in extracting the nitrogen-fixing enzymes from living cells, and the second has been the absence of satisfactory isotopes of nitrogen for "tracer" studies of the fate of nitrogen gas in the bacteria. Only

TABLE 2.—*Materials and energy requirements for the industrial production of ammonia from nitrogen and hydrogen (1 ton liquefied ammonia)*

Natural gas (92 percent CH_4)	26,000 cu. ft.
Catalyst for shift reaction	0.3 lb.
Synthesis catalyst	0.5 lb.
Caustic soda	8 lb.
Monethanolamine	0.3 lb.
Fuel gas	22,000,000 B.t.u.
Electricity	108 kw-hr.
Water	6,000 gal.

two isotopes, apart from ordinary nitrogen-14, are available: the stable heavy isotope nitrogen-15 and the more recently developed radioactive nitrogen-13. The use of the stable isotope is time consuming and needs expensive mass spectrometers. Nitrogen-13, on the other hand, has to be made continuously in a cyclotron and experiments have to be done within about 2 hours because of its very short half-life of only 10.05 minutes. Nevertheless, the tracer has been effectively used in some recent experiments with *Azotobacter*.

An important advance has been made with the development of methods for preparing cell-free extracts of microorganisms that fix atmospheric nitrogen. This discovery occurred, as is often the case, in a number of laboratories almost simultaneously and independently. In 1960, the Du Pont organization in the U.S.A. succeeded with *Clostridium pasteurianum*, the Long Ashton workers with *Azotobacter vinelandii*, the Wisconsin laboratory with *Rhodospirillum rubrum* and blue-green algae, and a California group with the sulphur bacterium *Chromatium*. In all cases, fixation depended on special methods of cell disruption and on supplies of special substrates. For the first time, it became possible to study the enzymes concerned in nitrogen fixation outside the living cell.

The Du Pont group found that sodium pyruvate was required for nitrogen fixation in extracts of *C. pasteurianum*. No other compound will initiate the activation of the gas. Since about 100 parts of pyruvate have to be added to the extracts to fix 1 part of nitrogen gas as ammonia it is clear that some intermediate product in the metabolism of pyruvate, rather than pyruvate itself, is required for nitrogen fixation. This intermediate factor has not been identified. However, it has been possible to separate two enzyme complexes from the extracts. The first is the reducing system which produces hydrogen from pyruvate and the second is the nitrogen-fixing component. Neither will, on its own, activate nitrogen gas, but when they are recombined active fixation takes place. An unexpected result was the identification of a new reducing protein, containing iron, which is required for the hydrogen production from pyruvate by this bacterium. The substance has now been isolated, purified, and named ferredoxin. It has a molecular weight of about 15,000, contains about 5 atoms of iron per molecule of protein, and is a most important electron carrier, especially in bacteria that live without oxygen. It is also found in green plants.

The enzymes that fix nitrogen in *C. pasteurianum* are present in the soluble parts of the cell; in *Azotobacter vinelandii*, on the other hand, they are located in particles which are components of the cell membranes. Another difference is that sodium pyruvate has no effect on fixation in *Azotobacter*—fixation is stimulated instead by unidentified reducing factors excreted into the culture medium during early growth.

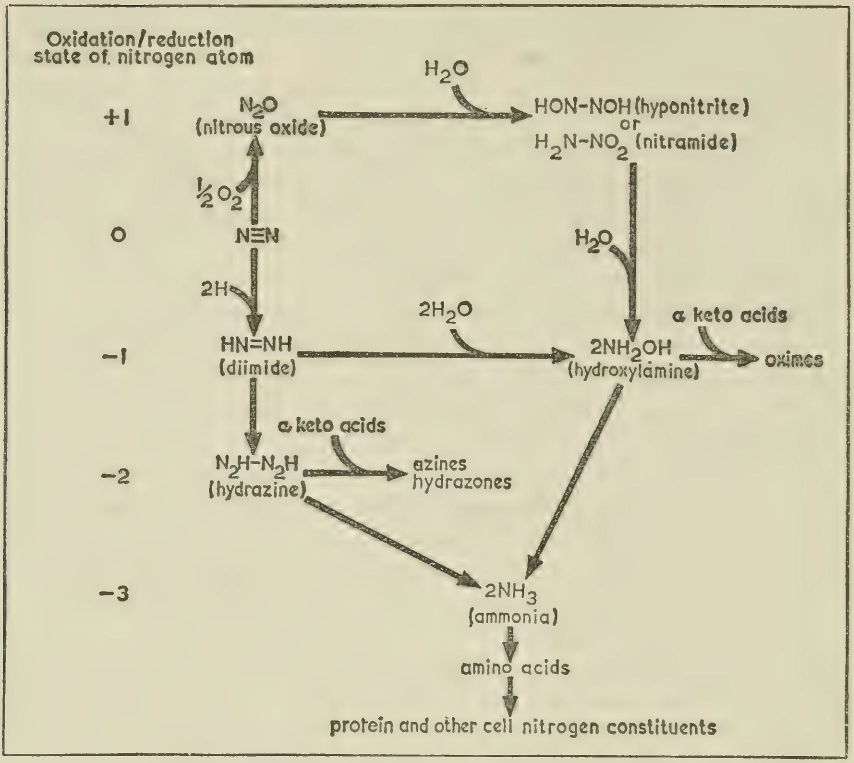

FIGURE 3.—Possible pathways of nitrogen fixation.

Inhibitors of fixation accumulate in cell-free extracts of *Azotobacter* cells during growth; these inhibitors may be destroyed by putting the cells in liquid air.

The various ways in which nitrogen gas might be converted to ammonia are given in figure 3. The uppermost route, via nitrous oxide, is not now thought to be likely; in fact, nitrous oxide is a potent inhibitor of fixation. Hydroxylamine and hydrazine have both been suggested as possible intermediates but the evidence for either is slim. Recent work with cell-free extracts of *C. pasteurianum* by the Wisconsin workers, using nitrogen-15, and by the Long Ashton group with extracts of *Azotobacter* using radioactive nitrogen-13, showed impressive labeling of nitrogen in ammonia but there was no detectable trace of hydroxylamine or hydrazine. The results suggest that *free* hydroxylamine or hydrazine are not intermediates in the reaction but do not rule out the possibility that they and other compounds may occur tightly bound to the enzyme protein. In fact evidence for enzyme-bound intermediates has come from experiments with *Azotobacter*, in which fractions exposed to radioactive nitrogen-13 incorporated more of the tracer than appeared in the form of ammonia.

This means either that intermediates between nitrogen and ammonia are tightly held by enzyme surfaces or that a labeled enzyme is formed, or both. When fractions were exposed to the tracer for brief periods, the isotope which was tightly bound to one protein fraction after the shortest exposure became dispersed into three protein fractions after a longer one. This again supports the theory that enzyme-bound intermediates are formed before ammonia, but no one has yet isolated or identified them.

It has been known for some time that trace metals including molybdenum, iron, copper, and boron are essential for nitrogen fixation, and, more recently, cobalt has been added to the list. Their precise functions in the process are not known. The technique of electron paramagnetic resonance (EPR) has been used in attempts to identify signals associated with free radicals, particular states of transition metals (iron, molybdenum, copper, manganese, etc.) and other systems containing unpaired electrons in bacterial extracts that fix nitrogen. Cell-particles that fix nitrogen prepared from *Azotobacter* were found to give signals for flavin semiquinone, for molybdenum in a highly

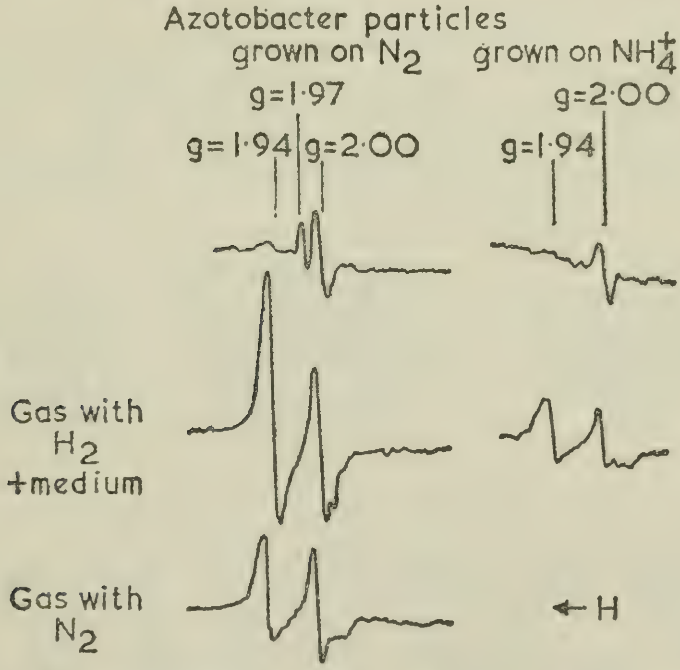

FIGURE 4.—Electron paramagnetic resonance spectra (EPR) of particles prepared from *Azotobacter vinelandii* (OP). Signals recorded in gauss (g). *Left column*, particles actively fixing nitrogen. *Right column*, particles that do not fix nitrogen, from cells grown with an ammonium salt as nitrogen source. *Upper row*, spectra of particles as isolated. In the nitrogen fixing particles there is a signal at g = 1.97 probably associated with molybdenum valency 5+. *Middle row*, after adding 10μl of culture medium in which the bacterium had been growing and gassing with hydrogen. *Lower curve*, gassing with nitrogen after the hydrogen and medium treatment.

oxidized state, and for an unidentified iron component. This iron factor is distinct from ferredoxin, mentioned earlier; in fact, ferredoxin does not produce EPR signals and is not present in *Azotobacter*. It was possible to reduce this iron and molybdenum by hydrogen and culture media factors and they were reoxidized by nitrogen (fig. 4). Comparisons with similar effects in the oxygen-fixing respiratory mechanisms suggest that nitrogen and oxygen are alternative targets for chemical reducing power that is transferred successively from hydrogen to iron to flavin and then via cytochrome to capture oxygen or molybdenum to capture nitrogen. Support for the view that molybdenum is a key link in the chain comes from experiments in which particles from cells that do not fix nitrogen proved to contain very little molybdenum.

Much work has been done on the mechanism of root nodule formation in clover, and similar studies have also been made in other types of flowering plants. It is clear that the host plant derives the advantage of the readymade products of nitrogen fixation and the microorganisms in turn get a supply of food that the plant makes during photosynthesis, as well as a favorable environment for nitrogen fixation.

Bergersen and his associates in Canberra have shown that the rhizobia bacteria in the nodules of clover are enclosed in a double layered membrane envelope. The bacteria are devoid of cell walls and are termed bacteroids (fig. 5). They are bathed in a solution of hemoglobin, which has a high affinity for oxygen, and this may provide

FIGURE 5.—Rods and bacteroids from root nodules. A, rods from a white ineffective nodule. B, bacteroids from a red ineffective nodule. C, rods from a green ineffective nodule. D, various forms of bacteroids. (After Virtanen.)

a mechanism for preventing free oxygen from coming in direct contact with the nitrogen-fixing system and competing with nitrogen for the reducing power generated by the bacteroids. When the rhizobia are cultivated outside the nodules they require nitrogen compounds for growth, such as nitrate, ammonia, or amino acids, as they are unable to fix nitrogen without the host plant. Nodules cut out or sliced soon lose their capacity to utilize nitrogen gas.

There are two current theories of the mechanism of nitrogen fixation in the nodules. The first is that fixation occurs in the membrane envelopes where the gas is activated and reduced to ammonia. Nitrogen is envisaged as the ultimate acceptor of the reducing power which is generated in the bacteroids and involves hemoglobin as a carrier. The host plant supplies the carbon compounds which are partially oxidized by the bacteroids and which then serve as a source of electrons for the reduction of the activated nitrogen. The products of the incomplete oxidation of the substrates serve as acceptors of ammonia from the fixation process which is needed for amino acid production in the bacteroids. The acids then become available to the host plant. This overall scheme is presented in figure 6. The second theory suggests that hemoglobin itself is the site of nitrogen fixation in the nodule. Future work will decide between these and other theories put forward to explain the symbiotic system.

The products of fixation appear to be similar in the nodules of leguminous plants as those already described for *Azotobacter* and *Clostridium*, that is, ammonia is heavily labeled with nitrogen-15 followed by glutamic acid. An interesting difference, however, has been found in alder nodules where the amino acid citrulline contained more nitrogen-15 than did glutamic acid.

Nodulated plants of soybean were first shown by Evans and his collaborators at Corvallis in Oregon to require minute amounts of cobalt (0.1 microgram per liter of culture solution) when relying solely on atmospheric nitrogen. Similar results were obtained subsequently with alder, *Casuarina*, and *Myrica*. *A. vinelandii* also requires 0.1 microgram of cobalt per liter of culture solution for nitrogen fixation. Since the amount is so small it is unlikely that it functions directly in nitrogen fixation but is probably required for the biosynthesis of enzymes involved in the fixation process. Cobalt is incorporated into vitamin B_{12} coenzymes in *Azotobacter* and in the root nodules of some legumes and alder. In our laboratory at Long Ashton we have found that *C. pasteurianum* also requires cobalt or vitamin B_{12} for nitrogen fixation.

What of the future?

Over 70 percent of industrial ammonia is used in the fertilizer industry and at present production exceeds demand, not because there is no pressing need for it but because the product is expensive. Al-

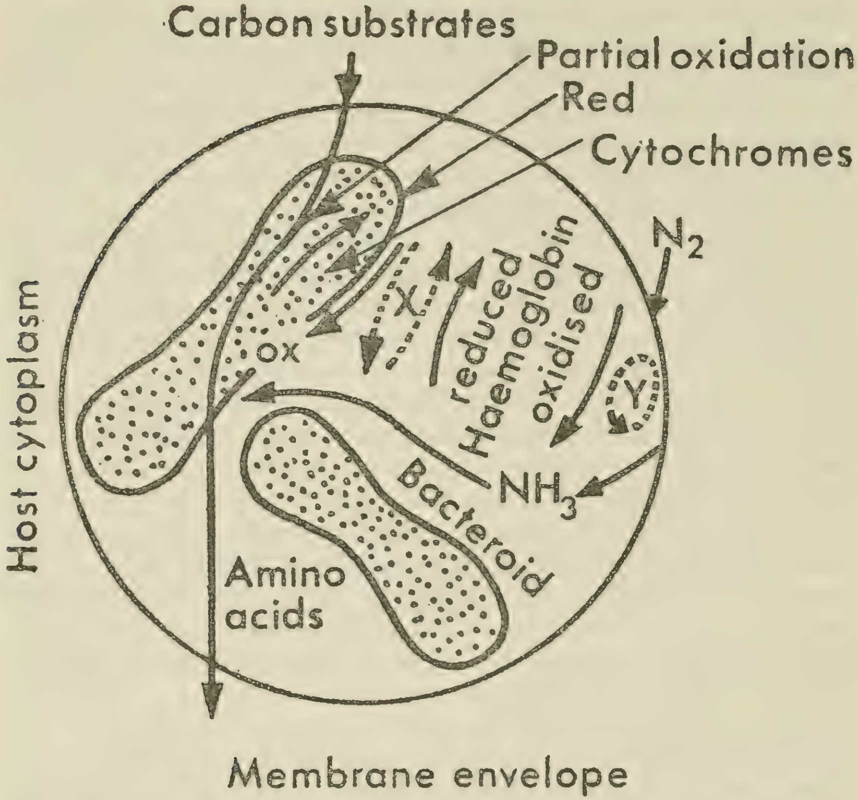

Figure 6.—A diagram of a hypothesis for nodule nitrogen fixation. One nitrogen-fixing unit is shown. Reducing power, generated in the bacteroids by partial oxidation of carbon substrates supplied by the host plant, is passed along an electron transport chain involving haemoglobin and is used for the ultimate reduction to NH_3 of N_2 activated in the membrane envelopes. X=unknown steps between the bacteroid metabolism and haemoglobin. Y=unknown steps between haemoglobin and the production of NH_3. (F. J. Bergersen. Bacterial. Rev., vol. 24, pt. 1, pp. 246–250. 1960.)

though the synthetic nitrogenous fertilizers are making a valuable contribution in various farming systems, the amounts employed are still small in comparison with the total amounts of nitrogen concerned in the world's crop production. Cereal crops in Britain remove about 50 pounds of nitrogen from an acre of soil, and a similar amount is present in about 1,000 gallons of milk; yet only 22 pounds of fertilizer nitrogen is returned to the soil, and a substantial amount of this is lost by bacterial denitrification or washed away by rain. As long as the world's population increases and arable land remains even at its present acreage there will be rising demand for nitrogenous fertilizers; unfortunately it is not economical to use them on a large scale in underdeveloped countries where, of course, the need for protein for animal and human consumption is greatest.

Most of the world's agricultural nitrogen is still supplied by soil microorganisms. A grass-clover pasture is capable of fixing over 500 pounds of nitrogen per acre in a year. Some interesting and exciting possibilities exist for inducing other types of microorganisms to fix nitrogen and encouraging symbiotic associations with other economic crops. Why should not grasses, cereals, or brassica crops or fruit trees have their own built-in symbiotic associations with nitrogen-fixing microorganisms? The answers to such questions—which could revolutionize agriculture and go a long way to producing food supplies cheaply—must await the results of fundamental research work on the basic mechanism and requirements of the fixation process in free-living microorganisms and in those in symbiotic association with plants. The immediate requirement is the separation and purification of the nitrogen fixing enzymes from cell-free preparations of microorganisms. There is no doubt that the mechanism of activation of nitrogen gas will be resolved eventually with the aid of chemical and physical techniques now being developed, but these studies must also seek an understanding of the cell organization and structure.

How the industrial process for forming ammonia from nitrogen and hydrogen works is still not completely understood, though it was developed at the turn of the century. It provides a relatively simple inorganic model for ammonia production, involving a solid catalyst based on iron oxide supplemented with salts of aluminum and probably those of molybdenum and vanadium, but it is significant that the main clues to the mechanism of nitrogen fixation have come from work with the biological system. It has been suggested in some quarters that by solving the problem of nitrogen fixation by microbial enzymes the process might then be exploited to produce nitrogenous fertilizers cheaply. This view may be too optimistic. There is no doubt, however, that some novel features in catalysis involving iron and possibly molybdenum will be found when the nitrogen-fixing enzyme system is eventually crystallized and analyzed by modern methods.

The Unity of Ecology[1]

By F. Fraser Darling

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It is rather extraordinary to be asked by educated people, what is ecology?—the more so, as economics is a word used by everyone and the substitution of the letter "e" for the diphthong "œ" disturbs nobody. Both ecology and economics, so properly derived from the Greek *oikos*—the home, are concerned with the ordering of the habitat and income and expenditure. Both sciences deal with communities and are, at simplest, observational studies of communities. Economics has tended to deal with income and expenditure symbolized in money, and the most dangerous economists have been those who have mistaken the symbol for the reality. There is now a refreshing trend to consider wealth as availability of resources, often natural and renewable and organic resources. The changes in the status of availability are subtle, depending on history, growth and movements of populations, and on technology. The resources themselves change in economic status with changes in human needs and desires, emergencies and fashions.

Ecology deals with income and expenditure in terms of energy cycles in communities of plants and animals, deriving from sunlight, water, carbon dioxide and the phenomenon of photosynthesis by which organic compounds are built. This raw definition is made more interesting by what I would emphasize as the *observational* study of communities of animals and plants. Here comes the possibility of that more general definition of ecology as the science of organisms in relation to their total environment, and the interrelations of organisms interspecifically and between themselves. The total environment includes all manner of physical factors such as climate, physiography and soil, the stillness or movement of water and the salts borne in solution. The interrelations of organisms and environment are in some measure reciprocal in influence; in animal life it is becoming increas-

[1] Presidential address delivered to Section D (Zoology) on August 29, 1963, at the Aberdeen Meeting of the British Association for the Advancement of Science, and reprinted by permission from *Advancement of Science*, November 1963.

ingly clear that important environmental influences are operative in what may be called psychological factors. Social behavior can be of critical quality ecologically, and this field serves, perhaps, to show how inadequate and imperfect as yet is our observation, especially of interspecific social behavior apparent in a complex biological community which includes man. The ecologist tends ultimately to consider man as a member of the indigenous fauna if man is a primitive hunter-foodgatherer, or as an introduced species if he is buffering himself against the environment by civilization, developed technology, and an export trade in natural resources. But there is one outstanding difference between man and the rest of creation ecologically. He is a political animal and in our day and age it is quite unreal to ignore the political nature of man as an ecological factor.

I am already giving the impression, perhaps, that there is such a subject as human ecology, a matter which has called forth some tart difference of opinion until very recently. For myself, there is no such subject as human ecology; there is ecology only, which must accept man as part of the field of reference; but man can have an ecological outlook in studying his own problems, whatever they are—medical, agricultural, or those of labor relations.

Haeckel coined the word oecology in 1869 and he had animals in mind. There is something ironical in the speculation that so ecologically perceptive a man as Charles Darwin probably set back the study of ecology for half a century because after 1859 the paleontological data concerning evolution had necessarily to be gathered. Ecology as we knew it 50 years ago was a botanical science primarily, handicapped by a certain restriction of vision associated with those whose eyes are focused on the sward. The early literature of ecology gravely neglected the influence of the biotic factor on vegetation; indeed, it was not until 1932 that the British Ecological Society published its second journal of *Animal Ecology.* Shelford was reacting to animal ecology in his studies of succession in the first decade of this century and his book on animal communities appeared in 1913, the same year in which C. C. Adams published his *Guide to Animal Ecology.*

Perhaps World War I explains the gap between 1913 and the early twenties, when Charles Elton's series of papers appeared, culminating in his *Animal Ecology* of 1927, giving us the fundamental ecological ideas of cyclicism in populations, food chains of varying complexity between species, leading to the concept of what is now known as the Eltonian pyramid, and the idea of animals filling *niches* in the functions of conversion of matter. Charles Adams, to whom I have already referred, made a profound remark to the effect that ecology was a study of process—process which is not necessarily progress, although the developmental quality apparent in the slow building

of biological communities was tacit in the phenomena of plant successions elucidated by the Clementian school of ecologists in America. Adams saw that the orderly thread of developmental succession could easily be broken or influenced by all manner of factors, but there was still the unbreakable thread of process or, in fact, history. There is at present some reaction against the idea of orderly succession to a climax state which is stable and continuing, because so many examples can be brought forward to show how natural phenomena such as hurricane, fire, and frost-heave—each at certain moments of biological significance such as a seed year or not—can make nonsense of orderly progression within the community under investigation. But they do not make nonsense of the idea and the trend, and the plain record of process of history brings us to a perspective of reality. It is part of the thesis of this essay that man was able to civilize by being a breaker of climaxes, giving him the stored wealth of the ages in plants, animals, and soil fertility with which to buttress himself against the environment and to enjoy the immense capacity for social evolution provided by the new ability to be permanently gregarious.

The concept of the dynamic biological community took a long time to mature—if we admit that it is even now much advanced beyond adolescence. Its development shows all the signs of what most of us detect some time or other in our personal investigations, inability to see much more than what we are looking for, or seeing without apprehending significance. Edward Forbes saw the concept of community clearly in his classic marine work of 1843–45, but his early death robbed Scotland and ecology of a luminous mind. The plant ecologists of the late 19th century, headed by Warming, made the concept of community a cornerstone of a growing science, and Tansley's famous paper of 1920 codified it and gave it greater significance. Tansley emphasized in this paper that conceptual arguments and hypotheses must be firmly based on observation of the vegetation itself and that one must constantly go back to the field. It was a necessary admonition in that laboratory era. Tansley developed then the idea of the community as a quasi-organism or organic entity, of the whole being greater than the sum of its parts. He made comparisons of plant communities with human communities, and remarked that lacking psychical awareness, instinctive cooperation did not develop—only symbioses of varying degrees—and that competition was the law of relationship. It was later, in *Vegetation of the British Islands*, that Tansley gave lengthy consideration to the biotic or animal factor in the expression of communities, realizing for example that a landscape of chalk downland, so old and English and accepted as natural, depends completely on the continued grazing of sheep. The very habitat of chalk grassland is man-produced by way of the sheep, yet it is

a habitat with well-defined floristic and entomological characteristics. We see here an example of organic evolution aligning itself with the long pursuance of human activity toward development of habitat. We have much to learn in this field in Africa, one of the main cradles of humanity, where man-produced habitats, such as savannah by the agency of fire, have developed their own ungulate faunas. Time has had its chance, unaffected by glaciation or major changes of climate.

Some of the shocks of human impact on biological communities may have turned the Americans the more surely to study such organic entities as inextricable webs of plants and animals; one of Shelford's pupils, W. C. Allee, expressed the notion of unconscious cooperation in biological communities, a concept so much easier to elucidate from studying plants and animals together. Some measure of the 'psychic awareness' not obvious to Tansley in 1920 was now seen to be present in the enlarged wholes of biological communities which we accept nowadays. Allee's unconscious cooperation was entirely scientific and utterly removed from the wishful thinking or pious hopefulness of Kropotkin's *Mutual Aid.* All the same, Allee brought warmth and light into a field which had tended to be chillingly botanical.

But the strings of past philosophy trail round our feet, making us conservative from a sense of prudence rather than reason. Judaic monotheism put man and nature apart, an idea strengthened by Cartesian dualism of mind and matter. The older Dionysian intuition of wholeness was heresy, and the ancient Chinese comprehension of a universe of checks and balances and compensations, in which man was essentially a part and no more, was unknown and unscientific anyway. Hence, far into our own day, man was not a proper part of the study of ecology. If you studied man you might have been an anthropologist or an archeologist or a historian, but if you studied ecology you dealt with nature as she was conceived to be and not with man. The notion of human ecology was considered not to be scholarly, though such a man as Patrick Geddes had made most illuminating contributions to the ecology of human life and had collaborated with J. A. Thomson who held this rostrum so long. Also, there were several people in manifestly defined fields such as geography, sociology, epidemiology, and social anthropology, who were jumping on this new bandwagon and calling their subjects human ecology. Ecologists would have none of it. They were aware of the wide spread of their subject and of their dependence on good taxonomy; there was some suspicion already that an ecologist might be a jack of all trades and master of none, and it was academic suicide to be an ecologist except incidentally to an acknowledged position in botany or zoology. The ultimate necessity of considering the biological community as a working whole, ecology being as it were the physiology of community, pro-

duced crops of errors where good botanists were less good zoologists, and good zoologists very inadequate botanists. In such an atmosphere of the titter behind the hand, it was not easy to embrace man and his possible ecology as well.

But for several reasons the intellectual climate is changing. The archeologist has shown in recent years that protocivilization is several thousand years older in the Old World than we had thought, and the primitive Folsom Man in the New World was much earlier than the accepted Quaternary immigration from northeast Asia. As we have learned how man lived, what he ate, how his houses were built, and what his devotional buildings signified, what movements he made, we have been compelled to speculate on the influences man has had on his environment through many thousands of years. Also, the dynamic world of this century, particularly of the past 20 years, has made us intensely and often painfully aware of change in the landscape. We have been rather roughly pitchforked into a world of democracy, so-called; into a world of human population explosion, into a world of mobility made possible by the invention of the internal combustion engine and the exploitation of fossil fuels. Land use has changed in character and so much more land has been used, often uncritically, following earlier patterns in different climates. The immense planetary buffer and reservoir of wilderness has shrunk in area and influence. Quite suddenly in these past 25 years and particularly since the last war there has been a shaking of confidence. The all-conquering technological man whose mind had the same characteristics as the bulldozers employed to grow groundnuts on a prodigious scale in Tanganyika is already out of date, although the breed is highly inventive and has in no way accepted defeat. There is apparent in politicians an unsureness: they look longingly and hopefully at the extreme technological man, but now it is perhaps as well to listen also to the biologists, not merely the ones who overcome noxious insects with magical rapidity, but ecologists as well.

What do ecologists offer? No panaceas or quick returns, so much as a point of view which restrains, shows the consequences of different types of action, and possibly how mistakes in land-use can be rectified; and why they were mistakes. Ecology is a science of identifying causes and consequences.

Here, I think, is where we may consider the place of history: the political situation and the changes brought about by individuals and ideas are the stuff of history and it is difficult to find out what influence man was having on his environment and what accommodations the organic world of nature was making. But it can be done to a considerable extent if we will give time to it and reconsider history in ecological terms for enrichment of our experience in making future decisions.

I would like to take as an example at random, pulling out one thread of English history, the course of sheep farming from Saxon times until the latter end of the Middle Ages. England was once a country of deep forest in the vales, with scrub on the chalk hills and wolds. Neolithic man could tackle the scrub with his tools of stone and bone, but not the forest. The Roman, better equipped, drove his roads through everything, making islands in the sea of forest. The Saxon came from forested lands, and working in his own ecological fashion soon reduced the forest to islands in a sea of cultivated or cleared land. The Saxon was a swineherd who undoubtedly valued the pig's snout in life as its hams after slaughter. Large numbers of herded swine must have been effective implements in scarifying the forest floor, disturbing or eradicating the pristine flora, influencing the physicochemical state of the ground and preventing regeneration, so that forest with undercover would decline and open woodland with fewer and fewer standards would be left. The food-gathering, soil-working pig may be looked upon as a pioneer when present in sufficient numbers, creating conditions in which a sward of grass could form in an increasingly parklike terrain. At this stage the sheep could take over, living on the sward, maintaining it and quite surely preventing the regeneration of woodland. The cattle grazing among the sheep also helped in the establishment of permanent grassland and were creating the possibility of fairly rapid conversion into arable land when pressure of population demanded extension.

Historical research has revealed that England and parts of southern Scotland were already important wool-producing country in Saxon times. That was the main economic function of the sheep, to produce wool; mutton was welcome but incidental. Some of the wool was used at home but it was an important item of export which allowed importation of Continental luxuries and even goods from the Levant. The great early development of medieval sheep farming did but build on the existing Saxon foundation. England was the principal European producer of fine wool. Italy, and later the Low Countries, were the large manufacturers of fine textiles. This interdependence must have helped in the unification of the medieval world. When England eventually produced her own fine cloth and cut down her export trade in wool, she inevitably crystallized more sharply. Italian bankers and merchants were prominent in the early trade and the Church was a pioneer agent in the spread of sheep farming to new areas. The Cistercian order particularly was responsible for extension into the north and west, where flocks of several thousands were kept by each foundation, such as Fountains and Rievaulx. Lords of the manor and peasants were all in this golden age of English sheep farming. The late Eileen Power gave a vivid impression in her Oxford series of lectures entitled *The Early English Wool Trade.* Reck-

oning from the number of sacks exported and allowing for some being used at home, there were probably 15 million sheep in England in the early 14th century.

It has probably been insufficiently realized what effect this vast sheep farming enterprise must have had on the landscape and wildlife. Despite the patches of forest, the fringes of parklike country in transition and gorse-clad commons, there must have been extensive bald spots where open-field cultivation and sheep farming between them would have destroyed all tree growth. The land of England was being mined of its stored fertility, but in such a favored area do we live that regeneration made good part of the loss in flora and fauna, seen and unseen, and consequently that much of the lost fertility.

Now comes the political act with its ecological consequences: this economically prosperous sheep farming era was wrecked by taxes in wool and on wool. Edward III was on the warpath, and wars, as we know all too well, are an expensive form of dissipation. The lords of the manor began to let their ploughed lands, and later their sheep also as going concerns. The rates of exploitation probably increased as the small men came in and had to create their capital. But the removal of the Wool Staple to Calais was the disintegrating blow. A system of husbandry was pretty well at an end, and before long the Reformation and the advent of American gold started a period of enclosure of land. This enclosure undoubtedly made for stabilization and a husbandry based on maintenance rather than pure extraction. The 18th-century introduction of leguminous crop plants and the more skilled application of the principle of rotation produced a conversion cycle of energy flow vastly in excess of that of the centuries immediately preceding. Not all of it was translated into human increase and economic prosperity. Hedges, hedgerow timber, increased leisure (for the few) for such country pursuits as hunting and shooting, which needed a varied landscape, and not least the emergence of the Romance poets in their delight in landscape, all contributed to diversification of habitat which the wild flora and fauna were quick to exploit in this favored climate.

The story in Scotland has been less happy. The more acidic soils did not withstand the sheep farming as well as those in England, if we exclude the millstone grits of the English Pennine Chain; the Southern Uplands of Scotland are still in sheep, but are deteriorating slowly. The Highlands, poorer and wetter and steeper, suffered their hardest blow of deforestation and the coming of the sheep in the 18th century, and have deteriorated to an ecological decrepitude which is plain for those with eyes to see. The political situation is not yet sufficiently ecological in climate to tackle this essentially biological problem of rehabilitation in a biological and geographical manner, although, as I said at the outset, it is improving.

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Let us now look at an older and larger pattern of animal domestication which has profoundly influenced the characteristics of flora and fauna over a vast area of the land surface of the Old World. The development of the highly specialized husbandry known as nomadism is far from primitive, though because it shows so many examples of arrested cultural growth we are apt so to consider it. Nomadic pastoralism is one of the surest means of breaking ecological climaxes. It is an insidious means also. There is not the primary traumatic onslaught of tree-felling, brush-grubbing, and ploughing that agriculture demands. Pastoralism is a penetration of terrain by a relatively small number of human beings. The landscape is not altered immediately and there are no considerable works of man evident to the eye. But numbers of grazing animals and close treading place selective pressures on the vegetational complex. Where fire is used, selection is more rapid. In effect, the herbage complex is simplified, and that means gaps in the original niche structure, with consequent overall loss in biological efficiency of the community. Broadly, the vegetation moves toward the xeric.

Nomadism postdates agriculture by an undetermined period running to some thousands of years. The specialization is like that of the seafaring man, no longer content to paddle about in the shallows with primitive raft or formless dug-out canoe, who has built himself a ship, beautiful in form because it is functional in crossing uncharted seas of uncertain temper, and who has developed the skill to navigate by the stars and sail the ship as if it were a live thing. Equally, the nomad did not just walk out into the sea of the steppe which stretches from the Crimea of Europe to the Yellow River of China: he was a riverside dweller, a forest-edge dweller venturing no farther than his domesticated animals could go and come in a day, or perhaps a little farther in the season of rains. Domestication itself probably arose on religious grounds, for the animals in sight, touchable and ready for sacrifice, were the embodiment of that which was desired, life-giving and life-enhancing. One of the characteristics of nomad stock is the capacity to herd close, and to move and feed and rest as one, a matter for selection conscious and unconscious, before man could go forth with flocks and herds on to the ocean of the steppe.

The sheep is the mainstay of nomadism just as it is the mainstay of the husbandry of wild lands today. The goat provides brains for the most part. The multiplicity of mouths are wealth-gatherers activated by four times as many superbly adapted legs and feet. Water is needed in minimal quantities, and the animal itself provides man with milk, meat, and warmth. But the nomad, interposing animals between himself and the generally inhospitable environment of the steppe, realized quite well that the several sorts of domesticated animals gave him different securities and desirable ends in an environ-

ment not as uniform as our school geography books would lead us to believe. Cattle are much more efficient converters, as individuals, of forage into meat, milk, and leather, and they can be used for traction and as weight carriers; but their heavy water requirements govern the possible nomadic routes. The camel, on the other hand, gives the nomad the greatest penetration or retreat into arid regions. Lastly, the horse was of great benefit as a producer of meat, milk, and tractive power. Domestication of these animals meant their presence where and when they were wanted, their mental and even physical characteristics so far modified that they did not move as quickly as wild ones. In consequence, the animals were in general on the ground for a longer period and in greater numbers than when they were wild. The nomad society arising gradually from the more sedentary agricultural group would early realize that overgrazing hung like a sword of Damocles. The price of the life-way of grazing animals is movement, the brand of Ishmael. In the ideal, agriculture is concentration of effort, or intensification: pastoralism is conscious, well-organized diffusion.

Yet man does not prefer constant or random movement. Even the most highly developed nomads do not go far, no more than 150 or possibly 200 miles of farthest distance in the year, and relatively long spells of pitched tents are desired. The women wish it so, caring nothing for floristic composition of the grazing. At best the nomad was on the chernozem soils of the Ukraine or in delectable valleys: at worst in the wastes of the Gobi or the Tarim Depression. Nomadism in its highest development did not occur until after 1500 B.C. and it came with achievement of that maximum state of mobility, the mastery of riding horses, as distinct from using this animal for traction.

Horse riding seems to have arisen on the plateau of northwest Persia. If you have ever ridden a pony of stocky Prjewalski type you will know the relief of getting off it for a rest: but once you have ridden one of the delicately controllable, long-gaited creatures of what we now call the Arab type, one's whole outlook changes on the mounted state. Man well mounted is a superior being, and the nomad soon geared his way of life to that which gave the male element swift and far range; even his eyes are a yard higher above the ground—no mean advantage. We cannot know the details of the dominant mutation which produced the dish-faced, long-necked, sloping-shouldered, fine-boned "horse of heaven," as it came to be called, but nomadic man quickly made use of it. Even his status changed, producing the chevalier, the caballero, and the knight, who were with us till the Land Rover came and the girls took over the pony clubs.

Now came maximum exploitation of the steppe environment, not only nomadism which, as I have said, is never over a very long distance, but in migration. The Indo-European tribes began their great

easterly migrations of thousands of miles through a thousand years, by which time they reached the Ordos country of the Yellow River. Within this time the civilizations of the Near East had learned the survival value of cavalry, and the Chinese finally learned the same lesson. They became an equestrian nation in all its elite grades. Expeditions were sent into Turkestan to bring back these "horses of heaven." One of the Pazirik felts, so miraculously preserved in the ice of an Indo-European grave since some hundreds of years B.C. in Siberia, shows a gay cavalier with impeccable military moustache on his Arab-type steed, meeting a seated man of Mongol type in Mongol dress.

Even the bronze art of the Indo-European nomad traveled over this whole region. These people knew their animals: just as a Navaho Indian boy today does not need to look at a horse to draw it in any posture, so the Indo-Europeans thought their animals—horses, cattle, sheep, goats—in lifelike simple terms; yes, but wild animals were of immense importance to them as well, whether ungulate or carnivore, and the dramatic moment of the lion's attack on the stag or antelope is often captured in a stylized but dynamic bronze plaque. There are the Scythian bronzes of the Kuban, the animal bronzes of Luristan, and at the eastern end the bronzes of the Ordos bend, which show a remarkable sensitiveness to animal form. The involved twisting stylized representation can be found also in the Celtic and Nordic scrollwork in metal and stone on the Atlantic seaboard. Tamara Talbot Rice has brought out this wide spread of nomad art in her book on the Scythians.

The archeologists have produced much of this material for us and set it in perspective, but zoologically they have not done so well. I suggest that it is up to zoologists to examine it with care, so that elk are not called stags, antelopes deer, or Urial sheep ibexes. The Saiga antelope also appears in these bronzes, unrecognized as such, and crested cranes seem of some significance. I myself have a complete Luristan bit, the cheek pieces of which are representations of elk. The use by the elk of the two posterior toes has been faithfully observed by this bronze-caster of nearly 3,000 years ago. How did this get into the Zagros Mountains? Had it come from the Caucasus? I also have what must be one of the earliest surviving representations of a peacock from Amlach in the Elburz country south of the Caspian. Forgive my digression, but I hope this nomad animal art will be examined in relation to possible distribution of species in the past and to ecological history.

Once the Mongols became equestrian, the backward, westward surge began, culminating in the empire of Genghis Khan which frightened Europe and conquered China for a spell until Kublai was himself

conquered by Chinese culture. So many of the remaining nomads of Central Asia are Mongoloid, even as far west as Kazakstan, but the Indo-Europeans also survive in pockets as far east as northern Afghanistan. By the end of the Mongol Yuan dynasty it is estimated that the human population of China had been reduced by 40 millions, which in itself must have had interesting ecological consequences for a generation or two.

The original fauna of this great region of the steppe survives in the mountain ranges, and the Saiga antelope is back on the plains in millions thanks to an enlightened policy of conservation by the Russians. But how long can nomadism survive? The brand of Ishmael produces this highly specialized form of society which in effect finds itself in a cultural cul-de-sac unable to evolve, whereas the less specialized and once handicapped societies at the edge of the steppe did evolve into the civilizations of today. Political feeling is against nomadism and the biological necessity of movement in pastoral nomadism if the habitat is to be conserved, is ignored. If there can be irrigation of the steppe, the obvious access of foods and fibers thus made possible means the nomads must change or go, and going is no longer possible in our contracting world. Farming nibbles at the alluvial river flats and the bore hole brings up fossil water also and cripples the wholeness of the habitat for the nomad. The Russians seem definitely to be eliminating nomadism, and such western nations as have any seem to be doing the same thing. Individual Britons have admired nomads and their way of life, but collectively or politically Britain is depressing nomadism: the Masai of the semiarid East African steppe are being eased out of their culture of arrested development in favor of Kikuyu and Sukumba, rapidly increasing tribes under the Pax Britannica, which were formerly despised and harried by the nomads. The reindeer Lapps are also finding their winter grounds falling within the agricultural penumbra and there is the social urge toward education, which tends to make the winter communities static. Nomadism will die, at the expense of sterilizing large areas of back country which only nomads could utilize, as far as domesticated livestock is concerned. Whether in the future we may return to controlled cropping of wild animals on wild lands unfitted to human settlement remains to be seen, but despite the tentative experimentation in Africa and the successful Russian work on the Saiga antelope, I have the feeling that man is still going to degrade much good wildlife country in an effort to farm it, before it is fully realized that the nature of such country in its water relations and soil characteristics precludes agriculture. There is some false moral self-delusion which makes modern governments try and fail rather than consider the wholeness of land-use ecology before formulating a land-use plan.

The mention of the pastoralism of wild lands by wild animals brings me back to a form of nomadism in the New World which has several points of interesting comparison with the early development of specialized nomadism in the Old World through use of the horse. We may take it for granted that the late flowering of civilization in the Americas was the result of having fewer and less convenient domesticable plants, especially cereals, and certainly fewer and less convenient domesticable animals. At the more primitive level, the North American Indians were forest and forest-edge and river-valley people. Their beast of burden was the dog, sometimes dragging a travois—a sorry means indeed. They too were near a great central steppe of prairie where the wild bison conducted its own seasonal movements which took it away from the haunts of men. Hunting of this animal meant enticement to newly burned grazing, and stalking which even included wearing a bison mask—a most unenviable method. Nevertheless, it would seem that from about the 16th century man was increasing the range of the bison by burning at the forest edge.

The advent of the horse by way of Mexico and the Rio Grande far into the Southwest was a major liberation for the American Indian. Horses were stolen or went feral and the terrain was that dry steppe phenologically perfect for this animal. Here man did not need to wait for the mutation which produced the "horses of heaven," for it was the less carefully bred examples of this type which so rapidly colonized the American steppe. The Spaniards lost their advantage when the horse went feral and spread northward and came into the hands of the Indians, who immediately rode.

There now occurred that specialization toward nomadism. The Indian could leave the forest edge and follow the bison. Thus, from the beginning of the 17th century until the middle of the 19th there was a strong man-induced extension of the bison's range and there was a rapid specialization by certain tribes to become horse nomads, in effect pastoralizing the wild bison instead of domesticated stock. Agriculture was minimal, carried on by the women, for the water situation was generally easier than in the Old World steppe.

This situation could have gone on indefinitely as a biological continuum, for the wild animal prevented overgrazing by its migratory habits, and the enlargement of bison-inhabited country by Indian fire seems merely to have been an enlargement of soil conserving prairie grassland rather than extension of less biologically productive savannah such as we see today in South America and Africa. It was the white man overrunning the West with domesticated stock, packing it and going away with the proceeds that devastated millions of acres at a much faster rate than the Old World nomads reduced the productive potential of the Asian steppe with close-herded domesti-

cated animals. Just as the Ukraine country of the Scythians came ultimately to wheat, so did the Middle West prairie become a bread basket. The Indians of the Middle West have gone the way of the Scythians.

We will not pause to consider the 19th-century calamity that befell the bison and the Indian, but what must be pointed out is that the sudden disintegration of this nomadism imposed by the wanderings of the bison, hit hardest those tribes which had specialized most in this way of life. Even today the observer can see that the horse tribes have come off worst in social and economic adaptation. The tribes which remained in the forest or at the forest edge are now woodsmen and construction men; the Pueblo Indians of the Rio Grande valley may be anything that the white man is, because of their urban tradition; but the horse tribes who accepted the exhilaration of liberty of distance and became what we have come to call Plains Indians, have found themselves in the deepest bondage of the drastically changed economic base. Now, as pastoralists, they are finding movement cut down, and yet a dawning ecology of land use is demonstrating the old truth, that the pastoralism of wild lands imposes movement of the animals. There is the continuing paradox of political tendencies to restrain the movement of people on wild lands, and scientific evidence that animals on wild lands must be kept moving. Only wild animals conduct this aspect of their lives without human direction, and on this shrinking planet of exploding humanity even the wild animals are having their necessary movements constricted. The threat to the elephant in Africa is not the killing that goes on but the merciless restriction of range and movement. Without the movement, habitat is destroyed and other species of wild animals suffer in train. A dramatic example of this trend has been the build-up of elephants in the sanctuary of the Tsavo Royal National Park in Kenya. Destruction of trees and bush by the elephants endangered the food supply of the rhinoceros, so that a period of long drought made this painfully apparent in the starvation of over 200 rhinoceroses. They were not short of water themselves, for the river never dried, but they died with their bellies full of indigestible cellulose fiber. I saw some of these creatures die and helped in the post-mortem examinations. I saw the wreck bush which would not even become a fire-climax savannah. I did not put the blame on the elephants.

I began this address with the statement that ecology was the observational study of communities of living things in time as well as space, and I repeated Charles Adams's dictum that it was essentially concerned with process. I have allowed myself to range about the world seeing man, plant communities, the communities of his own domesticated animals and some wild animals in dynamic process through

some thousands of years of man's most fertile years of culture, and you may agree with me that in any synecological studies it is difficult to exclude man or to be a plant or an animal ecologist. There is only one ecology. If we are to follow an ecological approach to the study of society—be it historical, sociological, agricultural, anthropological, or economic—we must keep in mind that man's habitat and human societies are not static. The cross section presented by a socioanthropological study needs amplification in time. Cultures are altering continually, progressing or retrogressing, and these trends, though subject inexorably to natural laws, are also the results of human behavior. Such action may have been unseeing of consequences in the past, but if ecology is to concern itself with human influences, and take its place at the council table of human affairs, it should accept the premise that our species has in many parts of the world arrived at the stage of mental evolution at which it is possible to foresee the consequences of various kinds of direct and indirect modifications of habitats and their biological communities. The well-being of the habitats and the human communities therein can be influenced and sustained by understanding the interrelationship of the biological communities in which we coexist.

I have put forward the thesis that man has been able to enjoy gregariousness and civilize as a result of learning how to tap the stored wealth of ecological climaxes—soil fertility, timber and other plants, and animals. His agriculture of annual or biennial plants sets back ecological succession and demands a high skill to maintain fertility; the general history of animal exploitation is of over-use. Are we faced with the proposition that civilization is a contradiction in terms; that civilization carries its own seeds of decay because ecologically retrogressive processes once begun cannot be checked? I believe there is some danger of this, but there need not be in an ecologically conscious world. The suffering planet has immense power of natural rehabilitation if given its chance and we are also learning how these wonderful integrated processes of healing take place. As I said earlier, ecology is the physiology of community. Understanding it we can avoid undesirable consequences. Perhaps it is necessary to say that I am not crying "back to nature"; our growing understanding of the physiology of community gives power of planned manipulation, finding other ways round to desired ends. The history of the Nature Conservancy in this country is a vivid example of men learning how to manage biological communities in a manner simulating the natural.

Man often reminds me of the Irish elk in that the elk's antlers could develop nonadaptatively in evolution as a byproduct of increase in body size, what Julian Huxley calls heterogonic growth. The enormous drain on the organism of growing so much nonfunctional calcium phosphate every year was too much once the prodigality of the

Pleistocene had passed. Well, man conjures from his mind ways of using resources unproductively, be it pyramid building in Egypt, temple building and human sacrifice in Mexico, and now defense and nationalism. Nationalism is the modern Irish Elkism. In a world where the only hope for man is internationalism, nationalism is the political ecological factor which prevents any constructive action to curb population increase. And withal, we are faced with the ironic paradox of splintering nationalism and pseudo-national costumes, with the dismal destruction of individuality inside them, which variability is as desirable in the social system as in the eco-system. Furthermore, I believe that the pressure of population on land is presenting us with an emergency earlier than the problem of growing enough food for the increase. Mobility by way of the internal combustion engine, vastly increased leisure by way of automation, and sophisticated modes of outdoor recreation are changing the land-use pattern far quicker than we are learning how to cope with it. Fifteen years ago the excuse of increased food production was enough to get rid of hedgerow trees in England; but at this moment the amenity value of such trees in such a populous country, needing the balm of the green leaf, far outweighs the small increase of food production which might accrue from their removal. The picture in the United States is of food surpluses but a very real shortage of recreational land. An Outdoor Recreation Bureau has been established as a department of government to help in planning the solution of this very considerable problem of land-use ecology in its widest sense, and I am glad to say ecologists have been brought in at the beginning.

It would be fantastic, nevertheless, to make the mistake now of so expanding the scope of ecology that it would become all-embracing, so that the ecologist would bog down in a morass of his own ignorance, and become the supreme irritating busybody. That, I think, was feared by those who years ago wished to exclude man from their studies and would not admit human ecology. Neither do I; there is no human ecology—only ecology—but in those sciences dealing with man, from political economy to social anthropology and archeology, there is plenty of room for the ecological slant of mind. As a corollary, I think that ecological research must become more and more the effort of teams of workers; the single worker will continue to discover beautiful expressions of phenomena, but the synecological studies in depth of habitats and communities which we need today demand far more than what one man can compass. Ecological studies are not designed ad hoc to solve land-use problems but to discover truth, and this high scientific approach must be jealously guarded, but thereafter ecologists can have a social conscience and apply their discoveries to the problems of land-use by man. The teams I envisage are not collections of

specialists, if they are to be successful, but, to borrow Tansley's expression, organic entities.

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Venomous Animals and Their Toxins

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[With 2 plates]

Venomous animals are found in every phylum except the birds. While it would be difficult to propose a figure for the number of species of venomous animals, because we do not as yet know about the possible venomousness of a score of arthropods and fishes, we do have some idea of the approximate number of poisonous species in most of the phyla. Of the 2,500 or so species of snakes found throughout the world, only about 250 are dangerous to man. Table 1 gives the names of some of the more important venomous snakes of the world, their adult average lengths, the approximate amount of dried venom contained within the venom glands of adult specimens, and the intraperitoneal and intravenous LD_{50} (the dose required to kill 50 percent of the test animals of a given group), expressed in milligrams per kilogram (mg./kg.) weight of test animal.

In the marine animals there are many venomous forms; at least 200 species of marine animals and freshwater fishes are known to be venomous or poisonous. Table 2 gives the names of a few venomous aquatic animals. The lethal doses for the marine toxins vary considerably. The geographer cone, *Conus geographus*, has an LD_{50} of less than 5 micrograms per kilogram; the venom of the round stingray, *Urolophus halleri*, has an LD_{50} of approximately 25 mg./kg. while the LD_{50} for the toxin of certain catfishes is of the order of 200 mg./kg.

Among the arthropods at least 700 species are known to be venomous. These include the black widow spider (*Latrodectus*), funnel web spider (*Atrax robustus*), the spiders *Lycosa raptoria* and *Phoneutria fera*, the scorpions, particularly *Centruroides sculpturatus*, *Tityus bahiensis*, and *T. serrulatus*, the bees, wasps, hornets, certain centipedes, millipedes, caterpillars, moths, ticks, beetles, and ants. Even among the mammals there are several venomous forms, the platypus and several of the shrews.

[1] Printed by permission from *The Times Science Review* (London), Autumn 1963.

TABLE 1.—*Some venomous snakes of the world*

Snake	Length adult (cm.)	Yield venom (mg.)	Intraperitoneal LD_{50} [a] (mg./kg.)	Intravenous LD_{50} (mg./kg.)
Europe:				
Viper (*Vipera*):				
Common viper (*V. berus*)	54–60	6	0. 80	0. 55
North America:				
Rattlesnake (*Crotalus*):				
Eastern diamond (*C. adamanteus*)	80–210	410	1. 89	1. 68
Western diamond (*C. atrox*)	74–175	230	3. 71	4. 20
Moccasin (*Agkistrodon*):				
Cottonmouth (*A. piscivorus*)	65–135	125	5. 11	4. 00
Copperhead (*A. contortrix*)	55–115	52	10. 50	10. 92
Coral (*Micrurus*):				
Coral snake (*M. fulvius*)	50–70	2	. 97	--------
South America:				
Rattlesnake (*Crotalus*):				
Tropical rattlesnake (*C. durissus terrificus*)	50–148	35	. 30	--------
New World pit vipers (*Bothrops*)				
Fer-de-lance (*B. atrox*)	125–175	80	3. 80	4. 27
Bushmaster (*Lachesis*):				
Common bushmaster (*L. muta*)	175–270	411	5. 93	--------
Australia:				
Tiger snake (*Notechis scutatus*)	95–150	25	. 04	--------
Asia:				
Cobra (*Naja*):				
Indian cobra (*N. naja*)	120–160	220	. 40	. 40
Viper (*Vipera*):				
Russell's viper (*V. russelli*)	90–125	130	--------	. 82
Krait (*Bungarus*):				
Common krait (*B. caeruleus*)	88–120	10	--------	. 09
Africa:				
Viper (*Vipera*):				
Puff adder (*Bitis arietans*)	100–145	130	3. 68	--------
Mamba (*Dendroaspis*):				
Green mamba (*D. angusticeps*)	225–285	80	--------	. 45

[a] Dose required to kill 50 percent of the test animals of a given group.

TABLE 2.—*Some venomous aquatic animals of the world*

Coelenterata:
- Fire coral (*Millepora alcicornis*)
- Portuguese man-o'-war (*Physalia physalis*)
- Sea nettle (*Dactylometra quinquecirrha*)
- Certain sea anemones

Mollusca:
- Geographer cone (*Conus geographus*), textile cone (*Conus textile*)
- Common octopus (*Octopus vulgaris*)

TABLE 2.—*Some venomous aquatic animals of the world*—Continued

Echinodermata:
- Sea urchins, *Diadma setosum* and *Toxopneustes pileolus*

Fishes:
- Stingrays, all species, particularly *Urolophus halleri*
- Scorpionfishes, all species, particularly the stonefish *Synanceja horrida* and the lionfish *Pterois volitans*
- Toadfishes (*Barchatus*), surgeonfishes (*Acanthurus*), stargazers (*Uranoscopus*), weeverfishes (*Trachinus*), certain catfishes (*Plotosus*, *Galeichthys*)

FOLKLORE AND FACT

Few areas of biology have stimulated the minds and superstitions of man more than venomology. In early times the consequences of the bites or stings of venomous animals were often attributed to forces beyond nature, sometimes to vengeful deities thought to be embodied in the animals. To these peoples the effects of venoms were so surprising and varied, so violent and sometimes incapacitating, that these substances were always shrouded with much myth and superstition. Even today considerable folklore concerning venoms still exists, particularly about methods of treating the injuries inflicted by venomous animals. During the past decade, however, a considerable amount of knowledge on the chemical and zootoxicological properties of venoms and plant poisons has been gained and one can now propose a few general considerations.

Venoms are complex mixtures, chiefly proteins, many of which are enzymes. Studies to the present time indicate that in those toxins rich in enzymes, such as snake venoms, much of the lethal and more deleterious biological properties appears to be more closely related to the nonenzymatic protein portions of the venom than to the enzymes and enzymatic combinations, although these latter substances certainly contribute to the overall toxicity of the venom. The effects of the separate and combined activities of these substances, and of the metabolites formed by their interactions, is complicated by the response of the envenomated organism, which may itself produce and/or release substances such as adenosine, bradykinin and histamine, which may not only complicate the poisoning but also may in themselves produce more serious consequences than the venom. The toxin of the bee, for example, is relatively nonlethal. It takes more than 150 simultaneous bee stings to kill the adult human; however, persons sensitive to bee venom may die from a single sting, the result of autopharmacologic changes.

The venoms of snakes are the most complex of all the mixtures of the animal toxins. They contain many enzymes, some of which, such as the proteases, phosphomonoesterase, phosphodiesterase, L-amino acid oxidase, 5-nucleotidase, cholinesterase, ribonuclease, desoxyribo-

nuclease, ATPase, DNPase, and hyaluronidase are being used by the biochemist, pharmacologist, and physician. However, these enzymes are not present in all snake venom. In general, Elapidae venoms are rich in cholinesterase and phosphotidase and poor in ATPase. Crotalidae venoms contain large amounts of hyaluronidase, phosphodiesterase, ribonuclease, and desoxyribonuclease, but little or no cholinesterase. There are species from both families that do not contain L-amino acid oxidase, even though this enzyme has been identified in the venoms of more than 55 species of venomous snakes. While there tends to be a relationship between enzymatic content and the genus of snake, it is not always possible to predict the enzymes present in the venom from data on closely related genera or even species. Not only do different species of the same genus contain different enzymes—or, as in some cases, different amounts of the same enzyme—but even snakes of the same species at different times of the year or under different environmental conditions may exhibit considerable variation in the enzymatic composition of their venoms. Such variations have little relation to the lethality of the whole venom.

A number of nonenzymatic proteins have been separated from snake venoms, and these appear to be considerably more lethal and in many ways more deleterious than the enzymes. These proteins also differ in number and molecular weight in the venoms of the three families of snakes so far examined. The first of these proteins was isolated from the venom of the tropical rattlesnake, *Crotalus terrificus terrificus* by K. Slotta and H. Fraenkel-Conrat in 1938. The fraction was called "crotoxin" and contained, in addition to the toxic nonenzymatic protein, several enzymes. It was given the tentative formula $C_{1230}H_{1776}O_{432}N_{328}S_{36}$; it had a molecular weight of 30,000 and was said to be approximately 15 times more lethal than the crude venom. Some years later, J. M. Gonçalves obtained three fractions from the same venom, all having specific biological activity: (1) "crotamine," with a molecular weight of 10,000 to 15,000; (2) "proteolytic enzyme"; and (3) "neurotoxin," which corresponded to crotoxin in its biological properties. Since the work of these investigators a number of chemical studies have been carried out on the nonenzymatic portion of snake venoms, and studies to date indicate that there may be no less than 6 and perhaps as many as 15 nonenzymatic proteins in most reptile toxins. Some of these fractions, such as "crotactin" and "crotamine," have been identified with specific biological activities; others appear to have several biological activities, while for still others we have not yet found the use to which their properties have been designed.

The composition of the venoms of marine animals varies considerably. Some coelenterate venoms contain: (1) several quaternary ammonium compounds, the most toxic of which is tetramethyl ammonium hydroxide or "tetramine"; (2) 5-hydroxytryptamine; (3)

histamine and histamine releasers; and (4) several proteins whose composition has not yet been determined, although there is a likelihood of one or several of these toxic proteins being peptides.

Studies on the chemistry of fish venoms have been limited by several factors. In many fishes there is no true venom gland; rather the venom is produced in certain highly specialized secretory cells which lie in dermal tissues that are not otherwise toxic. These cells are shown in figure 1. Unlike the snake venoms, which retain their zootoxicological properties even after 20 or 30 years, the fish venoms are extremely unstable, most of them losing their biological activity on standing for an hour at room temperature. In general, fish venoms are composed of 3 to 10 proteins and have little or no enzymatic activity. They are very unstable when heated and most of the toxic fraction is nondialyzable. On electrophoresis one to five fractions can be identified, only one or two of which appear to have biological activities that are deleterious.[2]

The venoms of some species of ants contain formic acid—which is very simple chemically—while others contain a toxin so complex by contrast, as "dendrolasin" $C_{15}H_{22}O$, β (4:8-dimethylnona-3, 7-dienyl) furan. Bee and wasp venoms are very complex mixtures containing a protein hydrochloride called "mellitin" and a number of other substances including at least seven enzymes as well as 5-hydroxytryptamine, kinin, and histamine. The venom of *Latrodectus* contains at least 12 amino acids. As most spider venoms, it is rich in glutamic acid and λ-aminobutyric acid. Six protein fractions have been separated by paper and column electrophoresis, and most of the toxic activity is found in one of them. The venom has spreading activity but no haemolytic activity and does not appear to inactivate cholinesterase. The LD_{50} for *Latrodectus mactans* venom is 0.550 mg./kg. test animal body weight.

The effects of venoms on the various organ systems of mammals and certain arthropods are quite well known. In spite of this, however, and at the present stage of our knowledge, it seems wise to avoid the arbitrary division of venoms into such groups as "neurotoxins, haemotoxins, cardiotoxins," etc., for while these classifications do serve some useful purpose, they have led to much misunderstanding and certainly to a number of errors in clinical judgment. It has become increasingly apparent from chemical and physiopharmacological studies that these divisions are oversimplified and misleading. Neurotoxins can, and often do, have cardiotoxic or haemotoxic activity, or both; cardiotoxins may have neurotoxic or haemotoxic activity, or both, and haemotoxins

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[2] D. B. Carlisle has demonstrated that some 60 percent of the dry weight of the venom of the weeverfish appears to consist of toxic mucosubstances, which can be separated into two albumins and an amino polysaccharide, although in the crude venom they are probably associated in a single complex mucosubstance. He has suggested that the 5-hydroxytryptamine contributes to the pain-producing property of the venom.

may have the other activities. Until the fractions responsible for the deleterious effects of venoms has been isolated and studied individually, and in combination, one must consider all venoms as substances capable of producing several changes, sometimes concomitantly, in one or more of the organ systems.

THE ANIMAL'S SIDE

Most data on the zootoxicological properties of venoms are based on our studies on mammals, which, of course, makes them of limited usefulness for understanding the design of some of the toxins in the animals' armament. The venom of *Latrodectus*, for instance, did not evolve and adapt to the problems existing between that spider and the mammals. Thus, it is not surprising to find that its venom is 20 times less lethal to some insects than it is to the mouse, while on the other hand it is also 10 times more lethal to certain other insects, which have not adapted in the same manner. Some sharks appear to be relatively immune to stingray venom while others from completely different habitats are very sensitive to this toxin. The California mountain king snake is highly immune to the venom of the Southern Pacific rattlesnake. A dose which would make a man dangerously ill, or may even kill him, has no observable effect on the king snake. The remarkable thing is that this venom, which produces such necrotic lesions in mammals, fails to produce even the slightest necrotic wound in the king snake. Thus, care must be exercised in applying data derived from studies in one group of animals to conclusions about the biological effects of a venom in another group of animals, or to data on the design, use, and adaptation of the venom (pl. 1, fig. 1).

Perhaps some considerations for classification might be proposed on the basis of the use to which the animal puts its toxin. Most venom delivered from the head, or more generally from the oral pole, of the animal is used during an offensive act, as in the gaining of food. This is particularly evident in the snakes and only slightly less so in the spiders. The venoms of these animals tend to have a higher enzymatic content than those delivered from the anal end, i.e., from the aboral pole of the abdomen, as those of the scorpions and bees. However, both of these groups use their toxins as part of their offensive armament; whereas the toxins of most venomous fishes and the poisons of certain amphibians, which are derived from dermal tissues, are used in the defensive armament. These latter toxins contain few or no enzymatic constituents. The snake uses its venom to immobilize or kill its prey, and to aid in its digestion. The prey is incapacitated by the toxin so that it becomes unnecessary for the snake to hold it after envenomation, thereby avoiding the possibility of being bitten. In most instances the venom kills the animal so quickly that it rarely has time to stumble more than a few feet from where it has been struck.

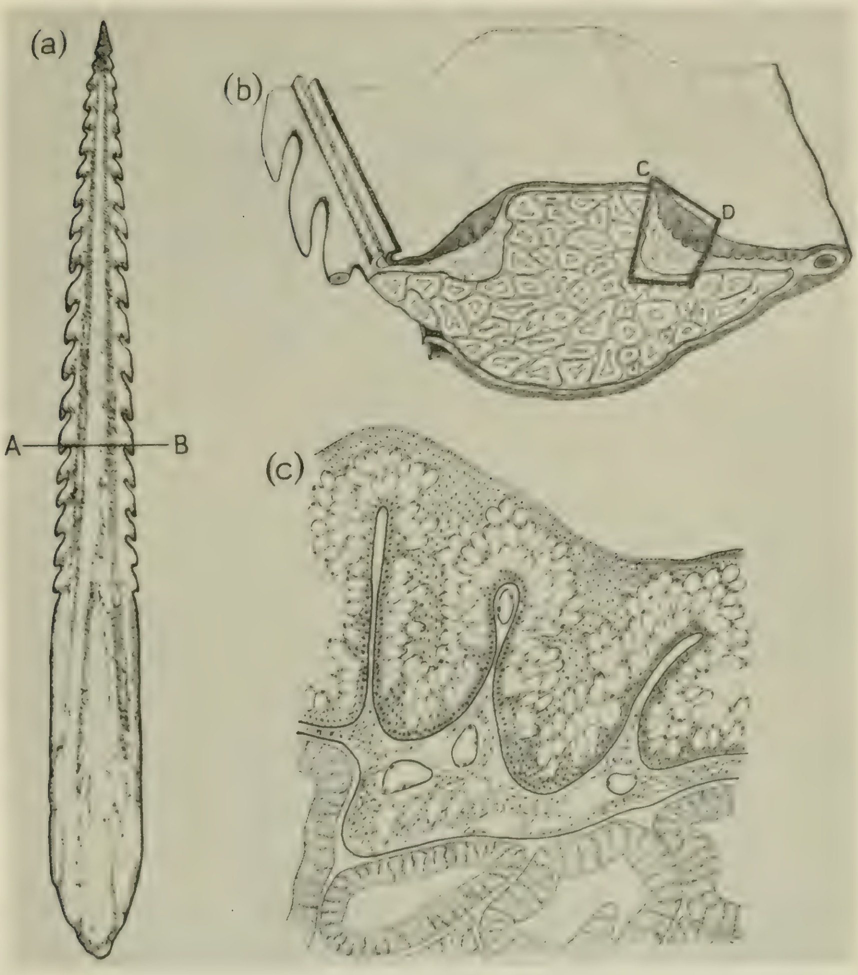


FIGURE 1.—The sting of the stingray showing (a) the spine; (b) a cross section through the middle of (a) at AB; (c) an enlargement of a ventrolateral groove, drawn from the area marked CD in (b). The large venom-producing cells are below the surface of the sheath.

We have some evidence on which to speculate that it would be to the snake's advantage not to kill its prey immediately on envenomation. It would seem that if the enzymatic components of the venom were to serve their best use they should be circulated, so far as possible, throughout the prey's body immediately prior to its death. The fact is that mice sacrificed and injected with the venom show less evidence of tissue autolysis than those killed by the venom within a minute of the poisoning. While snake venoms serve an important digestive function they do not appear to be absolutely necessary for this function.

With these several considerations in mind some insight into the physiopharmacological or zootoxicological properties of venoms is

obtained. *Crotalus* venom, for instance, causes deleterious changes in the tissues at the area of envenomation, changes in the red blood cells, defects in coagulation, injury to the linings of vessels and to a lesser extent damage to the heart muscle, kidneys, and lungs. While most of the North American *Crotalus* venoms produce relatively minor changes in transmission at the neuromuscular junction, the venoms of the South American species produce marked changes in nerve conduction and neuromuscular transmission. When *Crotalus* venom is injected intravenously there is an immediate precipitous fall in systematic arterial pressure with concomitant changes in venous and cisternal pressures, heart rate, and respiration. These changes are thought to be due principally to changes in the resistances of the pulmonary circulatory parameters, and to some extent changes in the cardiac cycle.

EVIDENCE OF USE

The black widow spider (fig. 2 and pl. 1, fig. 2) uses its venom to paralyze or subdue its foe and to a lesser extent to assist in digestive functions. The amount of the several enzymes in this venom is not sufficient to have any serious effect on man or most other mammals but they certainly play a part in the breakdown of the tissues of the spider's prey. In mammals, the venom induces a mild arterial hyper-

FIGURE 2.—Black widow spider and egg sac in web.

tension; it produces bronchial spasms and changes at the neuromuscular junction. Plate 2, fig. 1, shows the tarantula.

The venoms of some scorpions paralyze; they are among the most effective of the neuromuscular blocking toxins. The venoms of some of the parastic wasps are also potent nerve-muscle blocking agents. They are capable of paralyzing the junction in the body muscle masses of their host while having no effect on visceral musculature; the heart of the paralyzed host may beat for many weeks. The toxicity of some of these venoms is comparable with that of the bacterial toxins. Beard has estimated that 1 part of *Bracon hebetor* venom in 200 million parts of the host's blood is sufficient to produce paralysis in a late instar larva.

All of the fish venoms studied to date are known to be used by venomous fishes in their defense, particularly against those animals which feed upon them. On the basis of our findings in man it is assumed that fish venoms are capable of producing a similar degree of excruciating pain in other animals. I have injected small doses of a number of different venoms into myself and have found none quite as painful as those of the stingray and scorpion fishes. A pain-producing substance in the venom of the stingray, and other such venomous fishes (pl. 2, fig. 2), would appear to be a great asset to those fishes in their defensive armament.

There seems little doubt that the "convulsions" seen following stringray injuries, as reported by some of the early writers, were probably no more than reactions of hyperactivity provoked by the painful effects of the venom, rather than responses due to the direct effects of the venom on the central nervous system. This venom does not appear to elicit specific changes in the central nervous system except as secondary effects of cardiovascular changes. Stingray venom, and the toxins of many poisonous fishes, have a direct effect on the pacemaker of the heart, as well as on several other parameters of the cardiovascular system. Both small and large doses of this venom produce a hypotensive crisis in mammals. Small amounts of the venom appear to cause peripheral vasodilation while large amounts cause vasoconstriction. The venoms of the stingrays and weeverfishes (pl. 2, fig. 2) do not appear to have any effect on neuromuscular transmission.

Snake-venom poisoning constitutes a serious medical problem in some areas of the world. In Asia, excluding China, a few years ago approximately 30,000 deaths from snakebites were reported annually. Most of these deaths were due to bites by the cobras *Naja naja* and *Ophiophagus hannah*, the kraits *Bungarus candidus* and *B. fasciatus*, and the vipers *Vipera russelli* and *Echis carinatus*. In Africa as many as 1,000 deaths a year may be attributed to snakebite. Most of these deaths are due to bites by the adders *Bitis arietans* and *Causus rhom-*

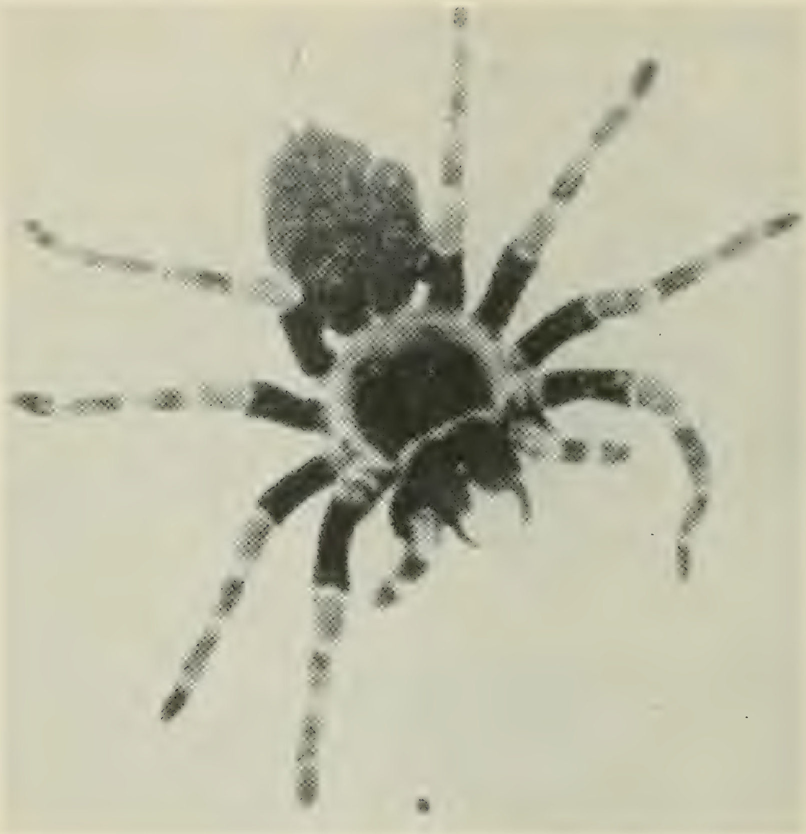
beatus, the cobras *Naja flava*, *N. haje*, *Sepedon haemachates*, *N. nigricollis*, and *N. melanoleuca*, and the mambas *Dendroaspis angusticeps*, *D. jamesoni*, and *D. viridis*. In South America approximately 3,000 deaths from snakebite are reported annually, most of which are caused by the tropical rattlesnake *Crotalus durissus terrificus*, the fer-de-lance *Bothrops atrox* and related species, and the bushmaster *Lachesis muta*. In Australia the tiger snake *Notechis scutatus*, the death adder *Acanthophis antarcticus*, the taipan *Oxyuranus scutellatus*, and the brown snakes *Dermansia* have all been implicated in deaths to humans. While most of the Pacific islands between 130° E.–170° E., New Zealand, the Hawaiian Islands, and some others are free of venomous snakes, New Guinea, the Solomon Islands, the Philippines, and Japan contain several venomous forms. The more dangerous snakes in Papua and New Guinea are the death adder and brown snakes, while the mamushi, *Agkistrodon blomhoffi*, is the commonest venomous snake in Japan. In Malaya the pit viper *Agkistrodon rhodostoma* is responsible for a large number of bites and some deaths. In the United States there are approximately 6,000 cases of snake venom poisoning reported each year, with an average of 14 deaths a year. The most dangerous snakes in that country are the coral snake *Micrurus fulvius* and the rattlesnakes *Crotalus adamanteus*, *C. atrox*, *C. viridis helleri*, and *C. scutulatus*.

Fortunately, since the advent of antivenins and their extensive distribution, the case fatality rates for snake-venom poisoning in the various endemic areas of the world have been declining very significantly. In the United States the fatality rate has fallen from 11 percent to less than 1 percent since the introduction and widespread use of antivenin. Today hyperantivenins are being produced by exposing the immunized animal to certain of the very active fractions of venoms in a mixture with the whole venom. It is quite probable that within the not too distant future it will be possible to recommend the use of a single antivenin for the treatment of envenomation by Viperidae, Crotalidae, and Elapidae.

Poisonings by arthropods are common in many areas of the world, although statistics on the incidence of the bites or stings of these animals are lacking. In Mexico during 1957 there were 1,495 deaths due to the stings of scorpions, while in the United States at least 26 deaths a year are attributed to the bites or stings of arthropods; almost twice the number attributed to the bites of the venomous snakes. Stingings by venomous marine animals are also common in many parts of the world. In the United States, where studies have been made on the incidence of stingings by these animals, it has been found that approximately 750 people a year are stung by stingrays, 300 persons a year are stung by the scorpion fishes, 300 a year by venomous catfishes, and an undetermined number by coelenterates, sponges, and certain

1. A nonvenomous snake devouring a live venomous one by which it had been bitten several times with no ill effects.

2. Fly's-eye view of black widow spider.



1. As a danger to man the tarantula has been overrated, though some South American species are lethal.

2. The greater weever. Protective spines are reinforced in venomous fish by association with cells that produce pain-producing toxins (c.f., fig. 1). The sting of the lesser weever is familiar to East Coast fishermen.

echinoderms. Only one death has been reported in that country during the past 50 years following a stingray injury.

The past decade has been a period of "tooling up" for the venomologist. Through the advent of chromatography, electrophoresis, and certain physiological monitoring devices, our knowledge on venoms has increased a hundredfold. During the next 10 years we should not only learn to separate and identify the various fractions of venoms, and to correlate them with specific biological activities, but we should discover how these complex proteins can be used to further man's studies of the cellular membrane and his fight against pain and disease.

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How Insects Work in Groups[1]

By JOHN SUDD

Lecturer in Entomology at the University of Hull, England

[With 2 plates]

WHEN PEOPLE SEE ANTS or bees collecting food, or the giant mounds built by termites in the tropics, they usually sense some fellow-feeling, some idea that insect and human societies are at bottom similarly constituted. The reason why these insects are held up to us in Scripture and in fable as models is that they can be seen going about tasks as men do, collecting and carrying food, building and fighting. Perhaps more important, they appear to combine in groups to catch, carry, or build things beyond the power of a single individual.

A termites' nest may be 2 meters high and a meter across at ground-level. Each of the grains of soil of which the nest is built has been carried separately and placed by a termite perhaps half a centimeter long. Clearly many termite-lifetimes of work were involved—just as many as the man-years of work in building a pyramid or in a space program. But termite mounds are not shapeless heaps; like pyramids they have a characteristic shape as well as a complex set of internal passages and chambers. The behavior of each of the huge number of termites has been directed to achieve this shape; each addition to the nest has somehow been brought into a correct relation with preceding ones. (See pl. 2, fig. 2.)

We can call the behavior of termites in building such a nest cooperative, using the word in its everyday sense, because we can see in it the three points we look for before we say that people are cooperating. These are, first that there should be a number of people working, second that they should gain some advantage by making something larger or more quickly than they could working alone, and last, and perhaps most important, that each man should adjust his work to suit that of his workmates.

[1] Reprinted by permission from *Discovery*, June 1963.

APPROACHING COOPERATION

In the termites' nest it is obvious that adjustment must have occurred; in other cases it may not be so obvious. Where mutual adjustment of behavior cannot be seen we must be careful to avoid the conclusion that any advantage gained from being in a group is the result of cooperation. The larvae of the white pine weevil feed under the bark of twigs, eating their way down towards the base of the shoot. The number of grubs in a shoot is always just enough to eat away the plant tissues all round the twig. If there are too many larvae, some are crowded out and cannot feed, while if there are too few, resin flows sideways from uneaten tissues into the damaged area and kills the larvae. Clearly the larvae gain an advantage from group feeding, but as there is no adjustment of their behavior to suit that of their fellows (no alteration of the rate of feeding or of the width of cut, for instance) the advantage is not the result of cooperation.

A closer approach to cooperation is to be found in young larvae of the jack pine sawfly. These caterpillars feed in groups on the foliage of *Pinus banksiana* (pl. 1); caterpillars feeding singly are very rare. The aggregation is not imposed on the caterpillars by the way the female laid her eggs. Groups form on needles where no eggs were laid, and will reform if the caterpillars are artificially spread out over the foliage. However, regrouping does not occur if the caterpillars are spread out on a sheet of paper. This behavior is related to a definite situation—feeding—and it is this which provides the key stimuli.

A. W. Ghent has shown that groups form around feeding caterpillars which have succeeded in penetrating the hard cuticle of the leaf. The situation provides the necessary stimuli for grouping—the smell of damaged foliage and of a resinous secretion produced by feeding larvae. Since the small first-stage larvae have difficulty in biting through the cuticle, breaks in it are important for their survival. Young caterpillars make full use of any presumably lucky break in the cuticle by extending the cut edge. Therefore caterpillars feeding in a group are better able to feed and correspondingly more survive to their first molt.

As these groups are formed by adjustment of the behavior of some larvae to use the success of others, the caterpillars can be said to cooperate in exploiting these situations. They respond to the evidence of success—the smell of damaged leaves. The cut in the leaf is the only link between members of the group, for sometimes larvae approach the opposite side of the cut to the larva that started it, and they move away from each other as they feed.

Larvae of the jack pine sawfly gather where the tough pine needles have been pierced. They are attracted by the smell of the damaged foliage.

1. Wood ants dragging a caterpillar to the nest. The arrangement of two pulling and one pushing is probably contributing little to the group effort.

2. A mushroom-shaped termite nest in grassland. Its characteristic shape—with a series of eave-like caps—shows that the work was not just pooled but that each individual contribution to the nest was coordinated in some way.

SUCCESS—A KEY STIMULUS

Among the truly social insects the ants are perhaps the most varied in their behavior. One of the wonders of the ant world is the nest of the tailor ants. These ants live in the Tropics, in a continuous range from North Queensland to West Africa, and always build their nests in trees. Unlike the many other tree-dwelling ants, their nests are made by drawing living leaves together to form envelopes which they secure with silk threads produced by their own mature larvae. In West Africa the French zoologist A. Ledoux has shown that leaves are bent to form nests in two ways: Either two nearby leaves are drawn together and their edges held in a tissue of silk, or a single leaf can be rolled up to form a tube.

The rolling-up of leaves to form the second type of nest is most interesting. The leaf is not rolled up in a logical way by a group of ants collecting at its apex and pulling it back under the leaf-blade. On the contrary, ants begin pulling at any point around the leaf margin, and they pull singly, not in groups. These first efforts are mostly abandoned, and some ants leave the leaf altogether, others merely move to another point on it—particularly to places where the leaf is already bent, either naturally or experimentally. Soon some ants succeed in bending the leaf edge. Because of the arrangement of veins in the leaf this is more likely to happen at the tip of the leaf than at its sides.

Throughout the process ants let go of the leaf and move about on its surface before they settle again, and these ants are attracted to places where bending is well advanced, so that they add themselves to the most successful groups. In this way the efforts of the ants are gradually concentrated at promising sites, usually the tip of the leaf, which are drawn down under the leaf blade. As the successful party moves down the leaf, ants pulling at the sides are drawn in too. Finally, when the leaf is doubled back, ants appear carrying larvae and close up the gaps with silk. How they are called in at this point is not known.

There are a good many similarities here to the case of the jack pine sawfly. Although ants are in general attracted to one another, those which are beginning to pull leaves do not aggregate in this way. The groups of ants which bend leaves form only as the work of bending progresses, just as the feeding groups of the sawfly did not form unless some larvae were feeding. Ant groups, like the sawfly groups, formed where there was evidence of success at the job in hand.

PULLING THEIR WEIGHT

The existence of cooperation has been most debated in the transport of prey by ants. Many ants are carnivorous and take insect prey back to their nest to feed their growing brood. In some species,

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though not all, a large insect is dragged home by a group of ants, some of which seem to be pulling together while others seem to be pushing. Some naturalists, struck by the ants' success in moving large prey, have concluded that this group transport shows a high degree of cooperation. Others, who noticed that some ants pull against one another and others simply ride on the prey while their comrades pull, thought that cooperation was absent.

In the wood ants, which occur in many parts of Britain, I have found evidence which seems to support both sides of the question. A few minutes after offering a large insect to these ants, a group of 5 to 10 ants forms round it. Many of these do not pull the prey at all and those that do, pull in different directions (fig. 1). There is a deadlock, and what movement there is, is often reversed and cancelled out in the next minute. At first, it seems that the ants are incapable of cooperation and that the more of them there are, the worse the confusion gets. But after 10 or 15 minutes, movement toward the nest starts and short of accidents goes on at a good rate. The group of ants is now usually small (pl. 2, fig. 1)—two pulling and one pushing is a common combination—and the ants' bodies are more closely alined with one another than in deadlock groups. Transporting groups seem to arise from deadlock groups when some ants leave the prey and others rearrange themselves so that their efforts are not opposed. The pushing ants are probably acquiescing rather than helping. At this stage the ants seem to be showing a fair degree of cooperation.

I have shown that changes which result in formation of a transporting group from a deadlock stem from behavior which can be seen equally well when a single ant is moving prey. The changes are basically part of the ant's method of coping with the difficulties it meets in moving prey. Perhaps the most obvious of these is a change in the mode of transport from carrying used for light prey, when the ant walks head foremost to the nest, to dragging, when it walks backward trailing a heavier insect behind it. This change seems to occur when the prey is about three times the weight of the ant.

The decision to carry or to drag is not, however, made once and for all at the start of transport. The ant changes from one to the other according to the gradient and smoothness of the surface, which affect the resistance the ant feels in pulling. This probably explains the existence of pushers and pullers in groups. Although the prey may be 10 times the weight of an ant, an ant pushing feels only a fraction of this and behaves as though it was carrying light prey. Actually the motive power is almost all supplied by the pulling ants, just as gravity supplies the power when a single ant carries prey down a deep slope.

Other remedies for difficulty in moving prey are not so well defined. When the prey an ant is dragging gets snagged on an obstacle, the ant swings itself through an angle of between 20° and 80° to pull at

a different angle, and it goes on trying new angles until it finds a line along which the prey will move. If this doesn't work it may release the prey and seize it again at a new position. These changes of position are not based on any knowledge of the type of snag; it is simply a question of "trial and error." If after a short time the prey does not come loose, the ant may abandon it. But if the difficulty in transport is not caused by, say, a grass stem, but by another ant pulling in the opposite direction, swings and changes of position may again result in finding angles at which the ants are not opposed to one another. This seems to be the way in which transporting groups are formed from deadlocks, although there is possibly also a tendency for pulling ants to aline themselves with the direction of movement once it has begun.

DISORDER, SEARCH, AND ORDER

These three examples have an underlying pattern in common, a pattern of three phases—disorder, search and order (see fig. 1). The gradual appearance of order in these tasks suggests that cooperation is not due to the imposition of a master plan but arises through the trial of many possibilities, those which are unsuccessful being abandoned. The trials are judged by effects, and the medium of communication between individuals which enables them to tell whether or not they are cooperating, is not incidental signals—scent, sounds, gestures—but the progress of the work itself. It is deeds that tell, not words.

Termites almost certainly build their strange-shaped nests by the same system. Professor P-P. Grassé has kept termites in the laboratory, and given them soil for building. At first they laid their pellets of soil at random, but later they were attracted to places where pellets had already been laid, so that pillars and walls were formed. When these were 4–5 mm. high, the termites began to build in horizontal sheets, joining one pillar to another. The progress of the work not only was the link between the work of individual termites, but also provided the cue for a change from vertical to horizontal building. Grassé calls this stimulatory effect of work "stigmergy" (from *stigma*—'prick, stimulus,' and *ergon*—'work').

SUCCESS BY RANDOM CHANGE

Many of the movements in an animal's behavior are closely adapted to some rather restricted function, for instance, the pairing of the sexes. Here, since all males and all females of the same species are similar, the problems involved in bringing the pairs from the random positions in which they first encounter one another to the stereotyped position in which mating is possible, are predictable, and can be solved by a fixed program, a kind of countdown of standard movements and responses. This is provided by the courtship of many animals.

Disorder

Jack pine sawfly

young larvae find it difficult to
penetrate the pine leaf cuticle

Tailor ants

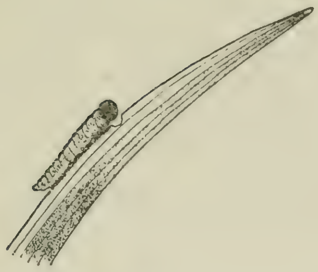
ants begin to pull at places wide
apart but leave places hard to bend

Wood ants

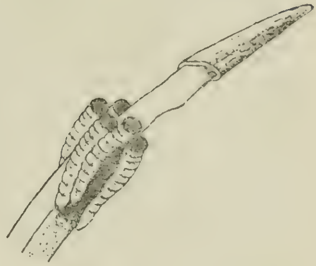
at first many ants gather round the
prey, pulling in all directions

FIGURE 1.—In many group activities a definite pattern of development is seen, as shown
successful, when order is

Search | **Order**



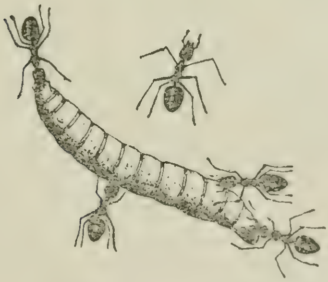
they move over the shoots until one is successful and starts to feed



the smell of damaged tissues causes larvae to collect to exploit the gap

they wander over the leaf but stay where bending is advanced (at apex)

this collective effort at places of success gives a typical rolled nest



unsuccessful, some move away while others change their angle of pull

these changes turn the prey to a position suitable for transport

on this and the facing page. Starting in disorder, insects search at random until they are established in the group.

In other situations, however, the animal is so much at the mercy of circumstances that it cannot develop a specific routine solution. This is nowhere more true than in a group activity, where the animal faces not only the variation in conditions but also the unpredictable and shifting behavior of its workmates. The tailor ant building a leaf nest or the wood ant dragging its prey solve these problems by changes in behavior which are not specifically related to the nature of the difficulty.

The success of this method is proved by the ability of tailor ants to build a nest with all types of leaves from the stiff broad leaf of an orange to the narrow flexible leaflet of a palm, and the ability of wood ants to move all shapes and sizes of prey over all types of surfaces. The undirected searching nature of their response to these conditions gives an appearance of chaos to group activities. But it is the same response which eventually finds a way through the difficulties.

Our Native Termites

By THOMAS E. SNYDER
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SINCE TERMITES are social insects and have a caste system and division of labor, there has been considerable interest in their habits. They also cause large amounts of damage and consequent money losses. This article discusses the termites of the United States, the damage they cause, and recent researches in termite control.

HABITS

Termites are most abundant and conspicuous in tropical countries where their high mound and tree nests attract the attention of the traveler. However, some termites occur in countries with temperate climates. In the continental United States, 41 living species (4 families) and 16 fossil (5 families) termites have been found. The living species have been found in 49 States. It is believed that all of these termites are native, with the possible exception of *Cryptotermes brevis* (Walker) which may have been introduced into Key West, Fla., from some nearby tropical island.

The nests of our native termites are inconspicuously located in stumps, logs, dead trees, fenceposts, utility poles, the woodwork of buildings, or in the ground. Subterranean termites may move from ground to wood and vice versa. The population of *Zootermopsis* colonies may be several thousand. The drywood termite colony (*Incisitermes*), reaching 5,000 individuals, is large. One quarter million individuals of a subterranean *Reticulitermes* colony constitute probably the maximum population, in contrast to several millions in some nests of tropical termites.

CASTE SYSTEM

The different forms or castes of these social insects include: The reproductives or primary macropterous pigmented king and queen, developed from winged adults; the brachypterous or short wing pad slightly pigmented supplementary reproductives, developed from nymphs, and the very slightly pigmented apterous reproductives, also developed from nymphs; the soldiers or defense caste, which cannot feed themselves; and finally, the worker caste which do most of the

damage to wood, and care for the other castes (fig. 1). Where workers are not present, nymphs or pseudoworkers take over their duties.

The inhibition theory of caste differentiation first developed by Drs. A. L. Pickens and G. B. Castle of the University of California in the early 1930's has recently been substantiated by the Swiss entomologist Dr. Martin Lüscher (1952) in his studies of hormones. Their theory is that males, females, soldiers, and workers secrete ectohormones which inhibit the nymphal development of individuals of the same sex or caste as that of the form secreting the hormone. In small colonies where reproductive forms are fully functioning, the development of any additional sexual forms is inhibited by the secretions of the parent reproductive forms of the king and queen.

This substance is supposed to be distributed throughout the colony by the grooming habit of the individuals. Or each caste, if present in the colony in sufficient numbers, tends to delay or inhibit the development of the individuals of the same caste by a hormone regulation.

Dr. Lüscher found that this inhibitory effect can operate only when workers can touch the functional reproductives. He theorized that it is the saliva, feces, or exudates of the reproductives that possibly contain an ectohormone that is the inhibiting agent. The surplus supplementary reproductives are eaten by the workers. If contact is cut off, the inhibiting influence that prevents the production of supplementary reproductives does not operate.

At the Fourth International Congress for the Study of Social Insects, held at the 600-year old University of Pavia, in Italy, I presented a paper (Snyder, 1963) dealing with the fate of the supplementary reproductives in small colonies of eastern species of *Reticulitermes* in the United States. In the spring, large numbers of supplementary reproductives are present in colonies before the annual colonizing flight or "swarm" of the winged adult. These disappear just before or at the time of the flight of the winged. Are they killed by the workers as being unnecessary in the parent colony where reproductives are already present? Or, impelled by the same stimuli as the winged, do they migrate—with or without workers—by subterranean galleries to form new colonies?

In the discussion which followed the presentation of the above, it appeared that there exist substantial differences between the habits of species of *Reticulitermes* in Italy and the habits of those species commonly found in eastern United States. In Italy, *Reticulitermes* colonies are headed only by supplementary reproductives, whereas in the United States colonies are commonly founded by winged or macropterous adults. In France, both reproductive forms found colonies.

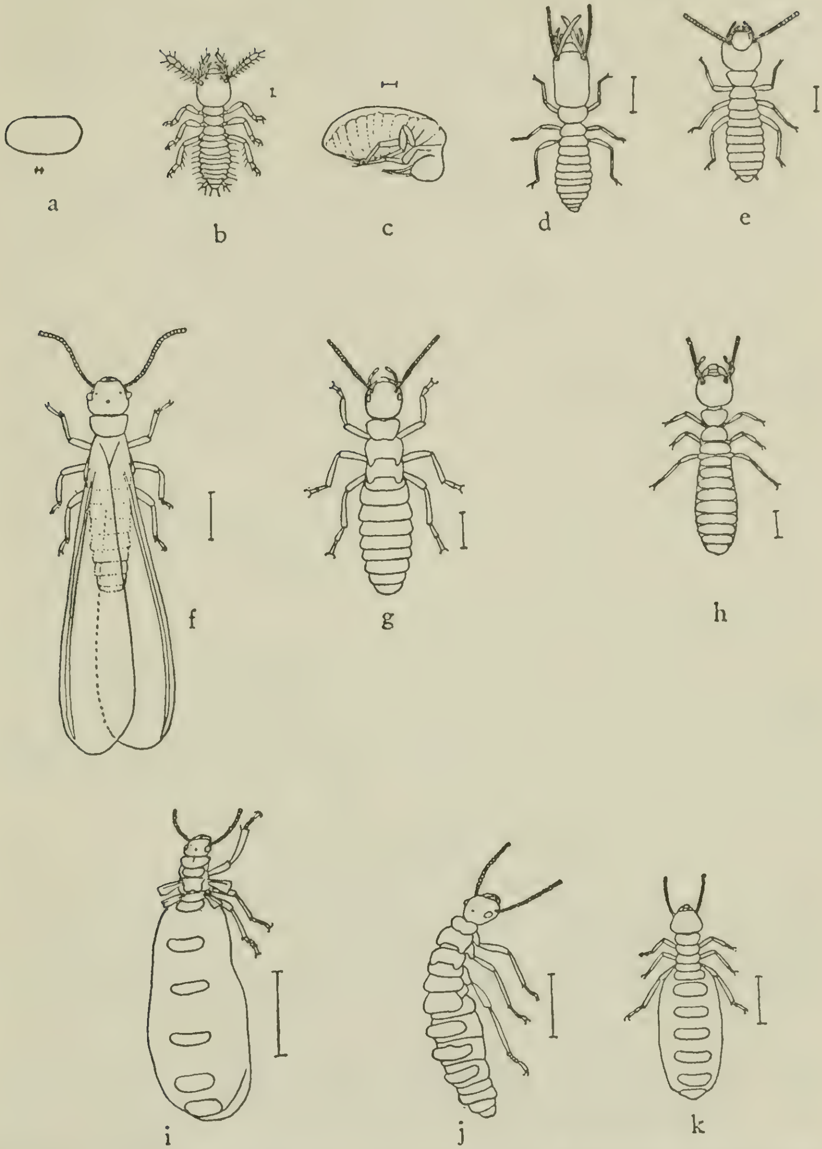

FIGURE 1.—Life cycle of the common subterranean termite *Reticulitermes flavipes* (Kollar). (a) Egg. (b) Newly hatched nymph. (c) Immature nymph in quiescent or resting stage. (d) Soldier. (e) Worker. (f) Sexual winged adult. (g) Brachypterous (young) reproductive form. (h) Apterous (young) reproductive form. (i) Primary or macropterous queen. (j) Brachypterous supplementary queen. (k) Apterous supplementary queen. All enlarged. (Courtesy U.S. Department of Agriculture.)

There are probably differences as well in the frequency with which colonies are headed by macropterous reproductives or by supplementary forms of Pacific coast and eastern species. Apparently fewer colonies on the Pacific coast are founded by primary reproductives than in the Eastern States.

COMMUNICATION

Dr. A. M. Stuart, an entomologist from New Zealand, now at the University of Chicago, in 1961 published on laboratory experiments with trail-laying by *Zootermopsis nevadensis.* A substance secreted by a gland in the ventral part of the fifth segment of the abdomen produced a clear-cut trail following. The nymphs are often seen dragging their abdomens along the ground when moving, thus bringing the fifth segment in contact with the substrate or surface. The substance from the gland can quite easily escape from the reservoir onto the surface on which the insect is crawling. Nymphs accurately followed the path. It leads termites to follow a straight line to food.

In a later paper (1963a), Stuart found the trails which the termites follow to be odor trails. In southwestern United States and northern Mexico, species of *Reticulitermes* build shelter tubes straight up to a beam on walls of adobe houses.

Also in 1963 Stuart (1963b) discovered that there is a directional vector in the communication of alarm by *Zootermopsis.* This vector was a trail laid by an alarmed termite from the point of disturbance to the main area of the nest. Individuals are recruited to the site of alarm by following such trails. Alarm is transmitted principally by contact.

SPECIALIZED FORMS

Dr. K. Krishna (1961) listed systematically the protozoa of the family Kalotermitidae.[1] These low forms of animal life live in the intestines of about 500, or one-fourth, of the 2,100 known species of termites in a symbiotic relationship and contain enzymes which digest

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[1] Also in 1961, Dr. Krishna, then at the University of Chicago, now at the American Museum of Natural History at New York, revised the family Kalotermitidae. Several termites of the United States had their names changed. *Kalotermes jouteli* Banks of southern Florida was placed in *Neotermes; Kalotermes occidantis* (Walker) of Arizona was placed in *Pterotermes; Kalotermes arizonensis* Snyder of Arizona, *K. banksi* Snyder of Arizona and Texas, *K. milleri* Emerson of southern Florida, *K. minor* Hagen of California, Utah, and Arizona, *K. schwarzi* Banks of southern Florida and *K. snyderi* Light of southeastern United States were all placed in *Incisitermes* Krishna; and *Procryptotermes hubbardi* (Banks) of Arizona and California was placed in *Marginitermes* Krishna. Only a few species of economic importance are involved.

Such changes, however, are hard to accept by workers in economic control work and pest control operators, who have terms of "Kalis" for the termites, and "Kalo guns" for equipment in the control of drywood termites in California. They may find it difficult to refer to *Kalotermes minor* as *Incisitermes minor.*

the wood which they eat. Most of the more highly specialized termites do not contain these symbiotic protozoa.

There are other termites of interesting shape and habits, especially in the Southwestern States. The nasutiform termites, species of *Tenuirostritermes*, have a nasus or beak instead of biting jaws for defense. From this exudes an acidulous secretion which gums up attacking ants, usually at the pedicle or middle of the body. The soldierless termites, species of *Anoplotermes*, must rely on large-jawed workers for defense. The desert termites, species of *Amitermes*, destroy sound wood. Species of *Gnathamitermes* cover over vegetation and wood with earthlike tubes to induce decay, then merely scarify or erode the wood. These are highly specialized types of termites.

Further studies are needed on all of these unusual termites although none causes relatively serious damage compared with that caused by the lower or less specialized groups.

DAMAGE

Only 11 of our 41 species of termites of the continental United States cause serious damage.

For convenience in control, the destructive termites of this country have been grouped with: Dampwood types—*Zootermopsis angusticollis* (Hagen), *Z. nevadensis* (Hagen) of the Far West, and *Prorhinotermes simplex* (Hagen) of southern Florida; drywood types—especially *Incisitermes minor* (Hagen) of California, *I. snyderi* (Light) of southeastern United States, and *Cryptotermes brevis* (Walker) of southern Florida; and subterranean types— *Reticulitermes flavipes* (Kollar) common in the United States, except for the Far West, *R. virginicus* and *R. hageni* of eastern United States, *R. hesperus* Banks of the Pacific coast, and the arid land subterranean termite *R. tibialis* Banks of the Western States.

For the last 10 to 15 years there have been noticeable movements of termites. The large dampwood termite *Zootermopsis angusticollis* has been shipped in green lumber from the Pacific coast into 20 States east of its range but, so far as is known, has infested no buildings and has nowhere become established. Its spread since 1950 is due to the large amount of insect- and fire-killed timber salvaged and moved east.

Through the transportation of furniture, the drywood termite *Incisitermes minor* of Western United States and Mexico has infested houses in 12 States east of its range, but has not become established. *Cryptotermes brevis* has become a major pest of buildings in southern Florida and has damaged buildings in five States north of Florida, probably from infested furniture; this termite has not become established locally except in the Gulf States.

The dark, southern subterranean termite *Reticulitermes virginicus* (Banks), whose northern range was Washington, D.C., in 1951 was found at Philadelphia, Pa., and has been found on Long Island, N.Y., since 1959. The light southern subterranean *Reticulitermes hageni* Banks, whose northern range was Washington, D.C., was found in 1958 in a building at Trenton, N.J. It is believed that these last two northward spreads were due to the trend toward warmer winters.

Most States have only the subterranean types as injurious species of economic importance but California and Florida both have all three types.

The California Structural Pest Control Board at Los Angeles issues quarterly pest infestation reports by counties, giving the comparative amount of damage for the three types of termites. Averaged for 55 counties out of 58 for 1962 and 1963, the figures are: Dampwood 0.4 percent, drywood 33.8 percent, and subterranean 44.52 percent. The remaining percentage related to other matters.

For the entire United States, it is estimated that the losses caused amount to one quarter billion dollars.

CONTROL

PREVENTION

With the increase in the number of buildings constructed on concrete slabs on the ground and consequent increase in the number of buildings infested with subterranean termites, the less costly pretreatment of the soil with insecticides became practicable in the late 1950's. Before the concrete slab is laid, you must secure proper drainage, remove all wood debris from the building site, and saturate the soil with long-lasting soil poisons such as water emulsions of chlordane and dieldrin. This may save more difficult and expensive treatment after the house has been built.

FUMIGATION

The most successful method of killing drywood termites damaging buildings in southern California and southern Florida is to seal them with heavy Kraft paper or cover them with tarpaulins and then fumigate with heavy dosages of lethal gases. Of course there is no residual effect and the buildings may soon become reinfested. However, it would take a long time to build up new destructive populations.

DESICCATION

Dr. Margaret S. Collins, now of Howard University, Washington, D.C., has since 1950 been interested in differences in toleration of drying between species of our native subterranean termites (*Reticu-*

litermes species). She early discovered that our arid land *R. tibialis* is more resistant to drying than our common *R. flavipes*.

In 1959, Drs. Walter Ebeling and R. E. Wagner, entomologists of the University of California at Los Angeles, discovered that infestation or reinfestation after eradication of drywood termites could be prevented by treating susceptible timbers with inert sorptive dusts, silica aerogel, nontoxic to humans or animals. These dusts removed lipids of the termite epicuticle which caused a rapid desiccation and death of the termites. Later it was discovered that water soluble fluorides incorporated into the silica gels increased the effectiveness with increasing relative humidities. After the wax is disrupted, fluorides can act as contact insecticides.

In 1963 Dr. Collins, with Dr. A. G. Richards of the University of Minnesota, studied in the laboratory of that university the tolerance to drying of five eastern species of *Reticulitermes*. Included were the rather desiccation-tolerant *tibialis*, which loses water at a consistently low rate, three species that lose water relatively slowly but show great variability under experimental conditions, and a species *flavipes*, that shows a variable but relatively high rate of water loss. The desiccation tolerance of *tibialis*, which ranges from west to east, appears to be associated with a relatively effective waterproofing mechanism, a well-developed cement layer, and moderate size.

When treated to demonstrate the cement layer, species of *Reticulitermes* other than *tibialis* were found to have very small argentaffin granules in depressed areas, instead of the heavy scaly layer found in *tibialis*.

R. flavipes seems to have the least efficient transpiration-retarding mechanism—the fact that this species may outlive species having lower loss rates during drying is probably due to its large size. There also were differences in the survival times in the castes.

Transpiration resistance increases with age, in the absence of damage, as does the resistance of the waterproofing to damage. This results in the rate of transpiration in imagoes (adults) falling to about one-third the rate of teneral (not quite hardened) imagoes.

Size appears to have no influence on the rate of loss, though it can influence length of survival under dry conditions.

Under field conditions, *tibialis* ranges into more arid areas than the sand-dwelling *arenincola*, and both inhabit more arid situations than *flavipes*. In areas inhabited by both *arenincola* and *tibialis*, the former can be found most readily in logs and stumps on the surface in spring during periods of abundant rainfall. The latter may be taken at the surface during either spring or fall. In Florida, *virginicus* and *hageni* are found more easily than *flavipes* during dry periods in nonforested areas.

POTENTIAL CONTROLS

ATTRACTANTS

In the early 1960's Dr. G. R. Esenther, entomologist stationed at the Forest Products Laboratory, Madison, Wis., and a group at the University of Wisconsin published a paper on a termite attractant (Esenther et al., 1961). It was discovered that the subterranean termite *Reticulitermes flavipes* will follow a concentration gradient of an attractive material, a culture of the brown rot fungus (*Lenzites trabea*) on pine to find decaying wood. It was believed that such a potent termite attractant might be useful in termite surveys and control.

Esenther and Dr. H. C. Coppel of the University of Wisconsin in 1964 published on results on laboratory experiments continued in the laboratory at Madison, Wis., with the response of *Reticuliterms flavipes* to attractants from extractives and synthetics especially to extracts from white pine infected with the brown rot fungus *Lenzites trabea.* Periodically for as long as several weeks the termite would not respond to any attractant; the cause remained unexplained.

Receptors appear to be terminal antennal segments and hind tarsi. The reproductive caste gave the most positive response. Specific differences, between termite species and specific wood-decaying fungi, are being studied.

Field studies indicate that sterilized *L. trabea* infected wood is the best field attractant. A modified attractant insecticide unit was used: A sandwich of five corrugated fiberboard pieces in which the center and two outermost pieces were not treated with insecticides. The second and fourth pieces were dipped in either 1 percent chlordane or dieldrin solutions, or a massive dose of dieldrin was applied to a sandwich unit by shaking only the central piece in a plastic bag that contained 75 percent wettable powder. The last method caused the greatest mortality. Decayed wood contains both an orientating and feeding stimulus; synthetic attractants show poorer results because they may be orientative attractants only.

Apparently, attractants' usefulness in economic control work is not yet proven.

FUNGI

In the early 1960's Dr. A. E. Lund of the Koppers Co., Verona, Pa., obtained conclusive evidence in the laboratory that certain species of our subterranean termites (*Reticulitermes*) initiate attack on the wood of southern yellow pine without previous infection of the wood by wood-destroying fungi. Further laboratory studies (Lund, 1962, 1963) proved that there was an influence on eastern subterranean termites by wood-destroying fungi.

One fungus, *Lentinus lepideus*, produce metabolites (end products) that appear to be very toxic to termites. *Lenzites trabea* produces an attractant. *Poria incrassata* extended the laboratory life considerably. *Poria monticola* exhibited a somewhat repellent effect. Still other fungi seem to be neutral in effect. At least one of the common molds (*Penicillium* spp., *Aspergillus* spp., etc.) reduced the longevity and the termites' death followed shortly.

As yet some of these relationships are not supported by laboratory or field evidence.

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The Phenomenon of Predation[1]

By THE LATE PAUL L. ERRINGTON

"NATURE'S WAY IS ANY way that works." My students know I like that expression. As a generalization relating to the opportunism and adjustment of Life, relating to the eaters and the eaten, it covers the field.

Predators kill and eat the animals they know as prey, however they are able to do so. They prey according to their opportunities, their adaptations, and—sometimes—their psychological preferences. Their predation may be rather indiscriminate, that is, within common sense limitations. It may be highly specific, highly selective. It may grade into the related phenomenon that we refer to as parasitism. When the prey consists of eggs or sessile animals, it may not differ fundamentally in its operation from grazing by herbivores.

For that matter, certain peculiarly adapted plants may prey upon animals. Bladderworts capture and digest small crustaceans in their traplike organs. Pitcher plants and sundews take insect victims as a regular way of life. And, whether one thinks of bacteria or viruses as being predatory or parasitic or saprophytic, the basic natural laws to which they conform in their exploitation of the exploitable are still those applying to the phylogenetically higher organisms.

The common denominator throughout is exploitation of the exploitable; but, if we think of just that in considering the phenomenon of predation, we may easily oversimplify. For there has been a lot of evolution shaping the patterns of interrelationships of living things with each other and with their physical environments. Diversity and complexity in these interrelationships are wholly consistent with diversity and complexity in the forms of living things.

I do not advocate straining to distinguish between borderline cases of predation and parasitism, or trying to judge precisely where predation and parasitism leave off and exploitation of dead or dying organic material begins. Preoccupation with definitions in relationships that by their nature have much leeway in them can, I think, defeat under-

[1] Reprinted by permission from *American Scientist*, June 1963.

standing. Just where do we logically put the dividing line between what a feeding mosquito does in taking a meal of either blood or juices, what a spider does to a fly, a water bug to a minnow, a robber fly to a grasshopper, a sea lamprey to a lake trout or a whitefish? What a killer whale or a shark or a bird of prey or a wolf does in eating something, alive or dead? What a snapping turtle does when it feeds upon algae, scavenge upon anything dead, eats the tails off live fishes on a fisherman's stringer or grabs a coot by a foot?

Gradations exist, whichever way we look, and I shall not further belabor what seems to me the pointlessness of labeling categories beyond what the facts justify. Regardless of the opportunism common to a bacterial infection and a violent attack by a genuine tooth-or-talon predator, the obvious differences are such as to merit separate treatment; and there is plenty about the phenomenon of predation that may be discussed in ordinary terms of animals being sought by or escaping from other forms that would kill or eat them, or, of them, if they could.

ADAPTIVENESS OF PREDATORS

Relatively few mammals and birds are adapted to exploit only a particular kind of prey. One of these is the Everglade kite, which has a hooked beak that is exactly right for extracting soft parts from the shell of a single genus of snail, and so the bird lives. The Canada lynx and the Arctic fox may, on occasion, be all but restricted to only certain of the foods available to them, apparently because of their own lack of adaptiveness; on the other hand, their relatives, the bay lynx or bobcat and the red and gray foxes of central and southern North America, may readily eat a wide diversity of foods. Gray wolves having opportunities to do so may, by choice, prey almost exclusively upon white-tailed deer. But predatory mammals and birds collectively are omnivorous feeders compared to the vast numbers of insects that show rigid selectivity in their predatory (or parasitic) behavior. Far down the phylogenetic scale are extremely host-specific viruses and bacteria, as well as some showing great versatility. The virus of rabies, the bacterium of tularemia, and the roundworm causing trichinosis each can attack an astonishing variety of at least warm-blooded host animals.

Food preferences or hunting techniques based upon individual learning are not restricted to higher vertebrates, though they naturally tend to be prominent among the more intelligent animals. Next to man, I should say that members of the dog family—individual red foxes, coyotes, gray wolves, domestic dogs—can show as much special choice of prey as anything of which I know. The favoritisms and originality that some of these animals develop in their preying may at times result in unusually severe local exploitation of a vulnerable prey population. Even prey species that are living with notable security from other

predators may at times suffer from concerted canine predation—I have known instances of this sort of thing in my studies of predation by foxes and dogs upon muskrats and ground-nesting birds.

But, modern studies on predation by lower vertebrates have demonstrated that learning can have a pronounced influence on their food habits. Fishes learn to take certain food items. Frogs may prey selectively through experience. Also, in late years, I have been gaining an impression from various sources that some insects and other active invertebrates may have capabilities for more individual preferences than we commonly have thought. A morphologically advanced brain is not an absolute prerequisite to a psychology of learning and choice.

PSYCHOLOGICAL ASPECTS

Let us consider some of the ways that predation may be influenced by the psychology of either or both predators and their prospective prey—not forgetting that predators may generally take such prey as is easiest for them to get, suitable for their requirements, and recognized as food.

Some of the clearest examples of psychological influence in predator-prey relations are those in which adversaries do a good deal of testing out and appraising each other's intentions and capabilities. The caution that predators show toward dangerous prey may be illustrated by wolves sizing up their prospects for attacking moose, bison, or muskoxen, or by the behavior of minks in the presence of formidable muskrats; but a predator's decision to attack or not attack may be quite unrelated to any threat of danger to the predators, themselves. Wolves also appraise their chances with caribou that they have no reason to fear. Bird-hunting hawks may repeatedly test by preliminary feints the attitudes of small birds that could not possibly do more than to escape.

Prospective prey that displays alertness toward predatory dangers yet conducts itself in a recognizably confident manner may discourage predators from attacking or cause the predators to desist soon after an attack is undertaken. I think we should give many predatory vertebrates credit for knowing pretty well when a serious attempt is not worth going through with. Conversely, except for manifest injuries or helplessness, panic on the part of the prey may encourage attacks about as much as anything.

There may be, however, a still weightier psychological factor in some predator-prey relationships: social intolerance.

One aspect of social intolerance—territoriality, or the defense of an area—has been best studied in mammals and birds, in some lower vertebrates, and in a relatively few invertebrates. Even among the mammals and birds for which it represents most nearly characteristic behavior, territoriality may exist in virtually all conceivable degrees

of intensity, the year around or only part of a breeding season. It may represent either highly sterotyped or highly adaptive behavior.

A territory, as for a nesting pair of peregrine falcons, may be several miles across; or, as in some colony-nesting birds, approximately the distance that a bird can reach with its beak while sitting on its nest. For one species of East African bishopbird, a territory may have boundaries that are exceedingly resistant to change, yet, for a closely related species of bishopbird, a territory may be almost indefinitely compressible. There are examples of communal territories defended by whole colonies. There are examples of the defended territories of some waterfowl actually lying outside of the nesting grounds.

While usually directed against members of the same species, territorial exclusiveness may also take the form of antagonisms toward members of different species. Wrens and coots include species of birds that can be among the more savagely aggressive toward other species about territorial boundaries.

Savagely aggressive social intolerance is not necessarily restricted to defense of territories, as is illustrated by the mobbing of hawks and owls by crows and the mobbing of the crows, in their turn, by smaller birds. Social tolerances and intolerances may also be influenced by the traditions that either individuals or populations may build up. Much may depend upon what animals become accustomed to.

Concerning territorial and other intolerances, one may again easily regard Nature's way as being any way that works.

A wolf pack may lay claim to a whole watershed, and the wolves may jealously keep that area for themselves. Or, they may admit to their social order or their holdings neighboring groups of wolves or unattached individuals—depending upon interplays of wolfish (really doggish) formalities, necessities, and the tolerance or discrimination allowed by individual dispositions. The chief prey animals of these wolves in the northern Lake States and adjacent Canada are the white-tailed deer, which have social intolerances too weak to be much of a self-limiting factor; and the deer may increase up to such numbers that they starve and seriously damage their environment while so doing. At least under some conditions, an adequate population of wolves may hold the deer down to levels that are in better biological balance than populations not subject to effective predation.

Social intolerances of minks may not fit too well into the category of actually defended areas, but the intolerances do work to keep mink populations spread out. As essentially solitary animals, their winter densities on the marshes that are the most food-rich for them—the most generally attractive for them of which I know—seem to level off at between 12 and 20 minks per square mile. I have never observed that any superabundance of readily available food ever resulted in concentrations of free-living minks to the extent that individuals

would be likely to encounter each other with great frequency in their daily lives. It has always seemed to me that excess minks tend to withdraw from the mink-crowded places, though this might mean wandering or trying to live in ecologically inferior environment.

If North American minks have any one favorite food, I should say that it is the muskrat. Minks may at times subsist upon muskrat flesh almost as exclusively as wolves may upon venison—with the outstanding difference that the minks may not find the presence of large numbers of muskrats synonymous with availability of large numbers of muskrats as food. Our Iowa data show a peak fall population of about 9,000 muskrats living securely on a 935-acre marsh, despite the activities of about 30 muskrat-hungry minks. The distinction between availability to predators and mere presence of prey animals should be emphasized. In the case of our Iowa muskrats, the predation is centered upon overproduced young; upon the restless, the strangers, and those physically handicapped by injuries or weakness; upon animals evicted by droughts, floods, or social tensions; and upon what is identifiable as the more biologically expendable parts of the populations.

I do not think that predation should be regarded as a true limiting factor of these muskrat populations. To the extent that predation operates only incidentally, removing little except the wastage parts of populations that are more or less destined to be frittered away somehow through one agency or another, it may make little difference to the population levels reached or maintained if the predation losses are light or heavy. I should say that the dominant limiting factor of a muskrat population is still its own sociology, within the frame of reference imposed by the material features of its environment.

Another predator-prey relationship in which severity of the predation suffered by the prey may be most misleading in off-hand appraisals of population effects is that of the great horned owl and the bobwhite quail in north-central United States. Our year-after-year population case histories show heavy predation by low populations of owls upon either high or low populations of quail; light predation by high populations of owls upon either high or low populations of quail; and much variation in between. What counts in determining the populations reached or maintained is not that the owls have quail to eat or that the quail have owls to eat them. Both species are highly territorial and show a strong degree of self-limitation independently of each other. Big owl or small quail, neither under normal conditions permits itself to increase up to levels that are biologically top-heavy. Each of these two species has in this way much in common, though one is subject to very little predation and the other is subject to much.

In its workings, territoriality tends to separate the haves from the have-nots in a population, with the holders of "property rights" having

tremendous psychological advantages in whatever competition takes place. Proper consideration of this factor calls for some modification of conventional views as to the struggle for existence, the ruthlessness of natural testings, and the nature of predation. The favored parts of a territorial population that live in relative social peace and are well adjusted to their environmental resources may, in fact, have fairly easy lives. They may not have to do much more than to conduct themselves according to their ordinary endowments to live securely with respect to their ancient predatory enemies. In contrast, life can be anything but benign for the wastage parts of a territorial population, and these are characteristically vulnerable to such predators as have aptitudes for preying upon them.

Species having weak if any territoriality may show much more violent fluctuations. It is quite understandable that the less a population is self-limited, the more it must be limited by something else: by predation, parasitism, disease, emigration, malnutrition or exhaustion of food, exposure to climatic emergencies, and the miscellaneous troubles that become compounded whenever populations get out of bounds.

THE ROLE OF TERRITORY

Surely, one of the principal differences to be seen in predator-prey relationships of higher vertebrates and invertebrates is linked with the relative importance of territoriality in these phylogenetically differing groups. Between the extremes represented by the most socially exclusive of the mammals and birds and, let us say, oysters growing on top of one another, many forms have developed territorial behavior to some degree.

Lizards and fishes—among them chameleons, sunfishes, and sticklebacks—include territory holders at least during their breeding seasons. Although territoriality in lizards and fishes may allow great numerical abundance, populations of these forms may still show distinct tendencies to level off with increased crowding and, often, with apparent independence of predatory enemies. Phylogenetically down-scale a little more, we also have insects and crustaceans that are capable of displaying effective antagonism toward possible competitors; and their populations may have at least some of the features of thresholds of security and vulnerable overflows. I think of dragonflies perched on tips of cattail stalks and patrolling their holdings, and, if their behavior is not truly territorial in so doing, it looks like the next thing to it.

J. H. Pepper published, in the mid-fifties, a most informative comparison of the population dynamics of Montana grasshoppers and Iowa muskrats. As far apart in their taxonomic relationships and as diverse in their living requirements as grasshoppers and muskrats are, they may show social intolerances and habitat responsiveness that

appear, broadly, not too dissimilar. Parts of grasshopper populations may, as for the muskrats, be relatively well situated; other parts, crowded into inferior habitats or beset by the frictions of overpopulations, are more exposed to miscellaneous mortality factors, including predation.

I can now see that a good deal of the predation suffered by grasshoppers—which I had long assumed to be more random, more of a gradual-attrition type—falls instead in more of an off-and-on, secure-and-insecure dichotomy.

(I am reminded that once I had even felt that the predation borne by an abundant muskrat population was proportional to the numbers of muskrats and the predators preying upon them, whittling down the general muskrat population little by little. That was before any attempts were made to inquire more deeply into what was happening. With careful local analyses, it became apparent that the predation that suggested gradual attrition was not in fact working that way on the muskrat population as a whole; it was conforming to the same overall rules of order that the Iowa muskrat studies had been bringing out again and again, whereby parts of the population lived very vulnerably while other parts retained their security.)

When reexamining questions of social intolerances and population effects of predation in the Animal Kingdom, I do not feel surprised because of the fewness of pat answers that come to mind.

Predator-prey relationships are hardly likely to be unaffected by social frictions, established property rights, and complex behavior patterns just because the participants happen to be classed as lizards, fishes, insects, and crustaceans instead of as mammals and birds. Nor should the greater collective fecundity of lower vertebrates, with corresponding individual cheapness of life, be considered a complete explanation for the lesser territoriality of lower vertebrates. Even among higher vertebrates, the strongly territorial gray wolf with close family ties has, on paper, a far higher biotic potential than its prey, the deer and caribou that may congregate in tremendous numbers. Nor can the lesser territoriality of lower vertebates be wholly explained in terms of their lesser intelligence and lesser adaptiveness, for territoriality reaches some of its most pronounced evolutionary peaks in birds, which as a class are less intelligent and adaptable than are mammals as a class.

The point is, once more, that Life selects for what works out, irrespective of our human efforts to define and classify.

INTERCOMPENSATIONS

We may next consider something else that Life selects for, something that is very often interlinked with or a byproduct of territoriality. It is a tendency to compensate, one of the prime upsetters of both

theoretical and "common sense" calculations as to how things work out in natural equations.

Intercompensatory trends in rates of population gains and losses go a long way toward conferring a singular degree of biological safety upon species that are subject to vicissitudes. In a resilient population, severe loss rates may in effect substitute for each other without mounting up excessively high in their totality. Extraordinary losses through one agency may automatically protect from losses through many other agencies. The death of one individual may mean little more than improving the chances for living of another one. Furthermore, in some species, extraordinary losses may be compensated by accelerated reproduction, more young being produced in consequence of more being destroyed.

From these considerations, it can be perceived why I am not inclined to accept mere conventional vital statistics as a suitable base for appraising the population effects of predation. More may be needed than figures as to how many individuals are brought into the world and how many or what proportions die through predaceous agencies.

Whether the population resiliences permitted by the compensatory trends enable a species to escape being dangerously reduced by great trials, or to resist changes in status quo, or to fill up biological frontiers with explosive rapidity, they obviously can be an important part of Life. Whether the purposes of human manipulations of animal populations are to encourage or discourage a particular species, in connection with nature protection, fish and game management, or pest control, we cannot afford to forget the fact that natural compensations can nullify much of the thinking that fails to take them into proper account.

The renesting prowess of some popular game birds is sufficient to confound many of the pencil-and-paper figurings of laymen, who easily become emotional at the thought of a crow or a skunk destroying a clutch of eggs. To the bobwhite quail and the ring-necked pheasant, the loss of a clutch or two early in the nesting season does not necessarily signify a corresponding net decrease in productivity of young. For species that are constituted to hatch only one clutch of eggs per year and that have a long breeding season and several possible nesting trials with which to do it, half to three-quarters of their nests may fail and still allow the breeding females to fill their one-brood "quota" for the breeding season. The more resilient nesters among waterfowl seem to be almost as persistent and as ultimately successful in their renesting efforts. Within broad limits set by physiology and climate, it may not really matter whether the crows, skunks, raccoons, or other wild egg eaters plunder a large proportion of the nests or whether they do not. It may all come out much the same in the end.

Breeding resilience may also compensate for high juvenile mortality in some of the more prolific mammals. This, too, should not be confused with the mere production of immense numbers of young to allow for or to compensate in advance for heavy losses. Rather, the population adjusts to the social tolerances of the species and the status of the habitat. Extraordinary losses of young may *stimulate* reproduction. For the muskrats of north-central United States, averages approaching four litters during a breeding season may be born to uncrowded adult females living under favorable conditions. Averages as low as a litter to a litter and a half may satisfy crowded populations in the same kind of place. But, if the early-born young suffer very high rates of mortality—as through the agencies of floods and epizootic disease on the north-central study areas—even crowded populations may give birth to many additional litters that plainly would not have come into existence had it not been for the severity of the earlier losses. After the young of these resilient breeders are hatched or born, compensatory trends in loss rates go into a substitution phase. While a minimal loss of young during the rearing season is inevitable under the best of conditions, a lot of the postbreeding shaking down of overproduced young depends upon the extent that their environment is already filled up with their own species. The net population increases often tend to be according to definite curves or to reach certain density levels, often in conformity to year-to-year mathematical patterns that look unaffected by changes in kinds and numbers of predatory enemies, the impacts of the less sweeping deadly emergencies, and so on. We can thus see evidence of balancing and counterbalancing that make meaningless any calculations as to population effect based solely upon the numbers or percentages of individuals that may die through this agency or that.

Muskrat populations comfortably situated in rich environment may give birth to many young and rear most of the young born; those populations that are beset by endless stress may give birth to few young and rear comparatively few of them. When the social squeeze is on and life is hard, there are bound to be heavy losses from various agencies, including predation from different kinds of predators. Still, I cannot see that such predation actually operates as a limiting factor—at any rate insofar as something else is doing the real limiting. Particularly do I find it difficult to see why some predators, for example the mink, may be considered a limiting factor on the basis of the large numbers of muskrats the mink as a species may kill, as long as in the absence of minks the muskrats may neither reach nor maintain their numbers at perceptibly higher density levels than they do in the presence of the minks. The Iowa case histories of mink-muskrat relationship repeatedly support this view.

We may go on from quail and pheasants and muskrats and see similar evidences of social interplays and compensations in the extensive literature on population dynamics. Poison-depleted rat and ground-squirrel populations have responded to lessened social tensions by accelerated rates of increase. The red fox, despite sport and bounty hunting in north-central United States, not only maintains its numbers at high levels in suitable range but also, I should say, thrives with heavy hunting mortality. Heavily hunted deer populations produce greater numbers of twin fawns than the less hunted. Mallard ducks, though overshot by man, have remarkably low "natural" loss rates compared to blue-winged teal, which are relatively little subject to human hunting. Heavily exploited stocks of sport or food fishes have faster growing individuals than less exploited stocks in the same waters. The Iowa lake that most consistently produces the greatest numbers of large bullheads of which I know is at the same time among the most heavily fished.

Of course, one could easily overgeneralize. I am aware that many species of birds have practically no renesting in them. Some grouse may normally make but a feeble attempt at renesting and then only if their initial clutches of eggs for the season be destroyed before the laying birds have invested much time in incubation. The shortness of the summer does not leave Arctic-nesting waterfowl much time for renesting, at best, if the late-hatched young are to develop enough to fly out before freeze-up. Even the bobwhite quail may lose its renesting resilience under the influence of severe and prolonged drought. There are conditions under which the most resilient of species will not try to breed at all, under which there seems to be no chance for any kind of compensatory balancing, at any stage of life.

As concerns either the lack or the prevalence of intercompensatory trends in the population dynamics of invertebrates, I feel too unsure of myself to generalize. I do not have to go far in this direction soon to find myself outside of my radius of professional experience. Of the opinions about compensations expressed in the invertebrate literature, a great deal remains inconclusive. Many leading students of population dynamics of insects regard compensatory tendencies as of general application throughout the Animal Kingdom; another very respected entomologist regards compensatory predation as probably uncommon in insects.

Perhaps, it may be argued that, concerning phenomena in which almost anything can happen, everyone can make whatever choice pleases him, but I do not think that that is a scientifically fair judgment to make. In studies of the exploiters and the exploited, we deal with adaptations of long standing. We need not restrict ourselves to the Animal Kingdom to see this. Grass grows anew in response to graz-

ing, and part of the annual production of a pasture depends upon the grazing pressure that it receives.

PREDATION ON INVERTEBRATES

The literature on biological control has among its bewildering figures and variables and mathematical models and claims and counterclaims some examples of causes and effects that look quite clear. Some of the evidence as to controlling or regulating influence of predation upon invertebrate prey populations can be duplicated by experimentation practically at will, or verified by repeated observations of natural events that fall into patterns.

Granted that we must know what preys upon what, it is not disadvantageous to know about relative severities of predation drawn by the prey, provided that we do not thereby conclude overmuch. I have nothing against the idea of exploring what can be explored with the aid of theoretical means, but I would hesitate to endorse anything following the line of thought that a given theory must be correct because it has no alternatives its proponents would rate as logical. I confess also to a distrust of conclusions derived from mathematical models that assume more randomness of contacts between predator and prey than I am accustomed to see under natural conditions—though, by this, I do not contend that randomness cannot or does not occur in true-to-life equations.

In general, the more patently the evidence comes from the land—or the water—itself, the more reassured I feel as to its validity as any sort of proof, one way or another. And, while even long-term experimentation on the land with predator-prey (or parasite-host) relationships very frequently gives rise to negative or inconclusive results, there are enough convincing cases of populations of especially insect prey responding either to increased or decreased predator (or parasite) pressure to demonstrate causes and effects. Some of the examples coming out of biological control experiments are by now classics in the literature on predation. I suppose that almost everyone who has done much reading in biology knows about lady-bird larvae preying upon plant lice. Similar examples that are scarcely less celebrated have been reported from many regions of the world. Indeed, the books and review papers on biological control attest to a tremendous amount of collective experience with this sort of thing and to the frequency with which, among the invertebrates, a predator can influence the population levels of its prey; and the idea of managing entomophagous insects through environmental manipulation, establishment of "refuge stations" in intensively cultivated areas, etc., is not new in applied entomology. I am uncertain, however, as to how effectively this type of management may increase an economically desirable type of predation.

The role of insectivorous birds in pest control has been threshed over for decades, sometimes with extravagant claims and assumptions. In my opinion, the desirability of having birds around can be well advocated on grounds other than the quantities of insects that they eat, without straining to justify economically what is not economic. When it comes to appraisal of bird predation upon insects, worms, slugs, and the small creatures that do what we do not want them to, the questions continue to arise as to whether such predation does have a controlling influence or genuinely contribute to control.

The few case histories of control of insect populations through bird predation that look convincing to me have one thing in common: superlative intensity of predation. A small garden enclosed by luxurious shade trees and shrubbery may concentrate the feeding of a large number of birds and thus have its insect populations reduced by the sheer weight of the predatory effort exerted. A homely analogy may be seen in neighborhood robin depredations on the cherry crop ripening on someone's lone backyard tree. But, in considering predation by birds upon invertebrates on a more spacious scale, it becomes more difficult to argue from sober facts. The property on which I live never seems to have any dearth of earthworms, however much the local robins may be observed pulling them out of the ground or collecting them in their bills after rains. (Neither do the ground-plowing moles seem to affect earthworm numbers appreciably, as a spadeful of soil turned in any place suitable for earthworms will reveal at almost any time.) We see the chickadees working the tree branches, the flickers and meadowlarks out in the fields, the swallows feeding in the air; and we know that they are eating insects, perhaps of known kinds and in quantities that might be calculated, but, aside from that, what do we really know about it?

Considering predation by birds on a still more spacious scale, I am willing to concede that the early Mormon settlers of Utah may have had good cause to erect a monument to cricket-eating gulls. The gulls, flocking to feed on the hordes of crickets that threatened the Mormon crops, very possibly brought the crickets under sufficient control to save the crops; but, from what I have been able to learn about this event, it would seem to have been a matter of rather local concentration of gulls in response to a concentrated food supply; and I would doubt that the gull predation resulted in any significant population control of the crickets over truly immense areas.

This naturally leads to philosophical questions as to how much some degree of predation here and there and now and then by this predator or that may contribute to the control of an invertebrate species when added to its other mortality factors; and I am reminded, too, about all of the confusion between facts of predation and effects of predation that exists in the literature on vertebrates and invertebrates, alike.

The population effects of predation by raptorial birds upon mice and upon songbirds may be equated with the numbers of prey killed; so may predation by the mice and the songbirds upon the insects that these may kill; so may predation (or parasitism) by insect species upon each other, by the hornets, the dragonflies, the powerful biters and stingers of lesser creatures that cannot escape; and yet I should say that the grounds for imputing population control may be flimsy indeed without consideration of possible intercompensatory adjustments.

CONCLUSIONS

To sum up concerning predation as a phenomenon, with special reference to its significance in population control: As may easily be judged, I regard the outstanding source of error in appraisals of predator-prey relationships as confusion of the fact of predation with effect of predation. Apart from a number of extreme or dramatic cases of predation depleting prey populations in ways that are self-evident, my inclinations are to look very critically upon figures presented, by themselves, as proof of population effect. They may constitute no proof at all, however imposing they may be when superficially regarded.

For intercompensation remains one of the big answers of prey species—especially of the less fecund or the only moderately fecund of prey species—to predation losses as well as to many other losses. On the basis of my own experience as a student of predation, the best advice I have to offer anyone interested in exploring the subject on his own responsibility, or to those trying to obtain workable concepts of its mechanisms, is, in short: Watch out for the compensations in attempting to distinguish between what does or does not count. When compensations are important in population dynamics, they simply cannot be ignored in calculations as to regulation effects of mortality factors, if the truth is to be reached.

50,000 Years of Stone Age Culture in Borneo[1]

By Tom Harrisson, D.S.O., O.B.E.

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[With 4 plates]

When I had the privilege of becoming curator of the Sarawak Museum in 1947, no systematic archeology had been done in the island of Borneo and most of the published material on its prehistory was speculative or even subjective. Slowly, in the past 16 years, we have been able to accumulate an organized body of fact, starting in Sarawak itself, and subsequently extending to Brunei and in a preliminary way to Sabah (North Borneo).

We have reached down to the level of beyond 50,000 B.C. in our excavation of the Great Cave at Niah. But in considering prehistory in the context of a place like Borneo, it is necessary to recognize that as well as extending far back into the past it continues, living, in the present.

It is not possible to understand the living cultures of Borneo today without tracing back through their history into prehistory. This history (among peoples who until recently were really illiterate) is nevertheless firmly held in a most elaborate sung and spoken folklore. In this folklore, past events are often identified with specific persons, places, and numbers of generations back from the present. Though subject to even more error and argument than the work of Western historians, recent work in Borneo has shown that there is a great deal of objective value in this folk material; a considerable part of our Museum energies has been expended in collecting what is left of it, before the great old singers and story-tellers die out.

In several cases, we have followed up folk tales by actual excavation, and proved an association between spoken words and things in the

[1] Read to the Commonwealth Section of the Royal Society of Arts, on November 28, 1963, and subsequently awarded a Prince Philip Medal. From the *Journal of the Royal Society of Arts*, vol. 112, No. 5091, pp. 174–191, 1964. Reprinted with revisions by permission of the Royal Society of Arts.

ground. By and large, this folk information can be regarded as having a varying but appreciable validity up to 20 generations back, especially among people like the Kenyahs and Sea Dayaks, who use remarkable *aide-mémoires*—in the form of marked planks—to refresh the compositions of successive generations. After about 20 generations, 1 or 2 generations may represent centuries, and we move back, usually, into a world of spirits and psychoses. Nevertheless, even in this twilight of remembered thought, it is possible to identify distinct major events, such as the advent of Islam in the 14th century; the impact of great Hindu figures earlier than that; and the impact of iron early in the Chinese impacts of the T'ang dynasty.

I first became directly conscious of this stone age element in the present when I landed, by parachute, among the Kelabits in the far interior during the Japanese [Second World] War. They were then at the very end of an actual stone age—such as still persists on a massive scale in parts of Central New Guinea. They were still using stone hammers on stone anvils to beat out crude irons for their rice hoes and jungle knives. Among their most valued cult objects were peculiar conical stones, which I now believe represent pounders for root crops and other purposes completely lost since the arrival of rice. These people have lived above the 3,000-foot level in the remotest part of the island, less disturbed than any others in this constantly dynamic and changing island population. I also saw then, and have explored since, extensive systems of upland irrigation in remote areas and a tremendously impressive range of megalithic monuments, some of them junior Stonehenges, standing days of walking away in the jungle.

For these and many other "mysteries," the Kelabits have extensive explanations in their folklore. Following up these cult objects of stone, one finds they are common to many Borneo peoples. But none of the others have conical pounders. Among the Kenyahs and Kayans of Sarawak and Kalimantan, another form of adz is characteristically kept and believed to be a magical thunderbolt. Farther north, among some of the Sabah people, the earlier findings of the late I. H. N. Evans are extensively confirmed by further collection. There he found small squared adzes and some remarkable gouges, cigar-shaped and nearly a foot long. Along the coast and southwest, we find even more peculiar stone tools (since published in *Man*).

Without elaborating on this to the extent of confusion, patterns of different stone age cultures (in a simple technological sense) can be mapped over different areas of the island. But, of course, with the mobility of many of the groups—even in historic times for the Sea Dayks and others—it does not follow that the tools now found in this way within any area were originally used *there*. They may well have been brought from another island, millennia ago.

Now, gradually, we are finding some of the same tools in stratified excavation, in our cave sites and elsewhere. Only this year, for the first time, have we found the crescentic adz in situ. This, most puzzling, in a new sector of the Niah Great Cave well in the darkness; but not in the ordinary succession in the enormous cave mouth, to which I will refer again presently. Others of the cult stone-tools have not so far been identified by excavation within Borneo, though known outside.

There is another significant linkage between the protohistory of ethnology plus folklore and prehistory by excavation, which must be briefly mentioned in connection with my present theme. Stories are told (among some peoples) of the actual introduction of iron. The Kelabits register this as a sort of miracle transformation, where suddenly a man appeared, with the first iron tool; he was able to multiply his agriculture enormously in one splendid day.

As well as stories about iron, there are others about bronze, and these again are in several cases associated with cult objects. One of these cult objects, which has a 20+ generation genealogy, has recently been presented to the Museum by the hereditary owner, a Kayan who no longer felt his group had the necessary pagan basis and power to preserve it in its deep spiritual context. This figure, called Imun Ajo, is a superbly modeled small bronze of a man with a hornbill headdress, closely related to the D'ongson bronze age culture of Indo-China.[2] Imun Ajo is regarded as a sort of fossilized living person, in transformation from stone to metal. But the important inferences of stories about him (and others) is that there was an almost direct transition in Borneo from the late stone age (Neolithic) to iron. There was no real bronze age in between, in Borneo; which moved from a tremendously developed Neolithic bang to a massive explosion of iron (I believe).

We have now traced some of the actual ironworking sites in the Sarawak River delta, where metal is always associated with impressive debris of a Chinese trade, noticeably ceramics of T'ang-Sung date.[3] Using mine detectors, we have been able to plot some of these. One stretches for nearly a mile along a now silted-up creek; another, covering about 3 acres, has accumulations of iron slag down to 12 feet in depth—if it were not so inaccessible in what is now mangrove swamp, it would be extracted by bulldozer to provide Sarawak with much needed road metal.

This iron, in the living context of the great and difficult Borneo rain forest, had an even more radical effect here than in many places. It facilitated techniques for felling and clearing. And it provided a

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[2] Photographs and particulars will be published in a forthcoming issue of *Artibus Asiae.*
[3] See papers in *Oriental Art* and *Transactions of the Oriental Ceramic Society.*

means of boring long straight holes through hardwood to provide that wonderfully efficient weapon, the Bornean type of polished blowpipe, which can shoot a dart accurately for long distances, including into the forest canopy. The extensive evidence from analyses of the very large quantities of food bone we have been recovering from the stone age levels of the Niah cave (over a million pieces to date) underlines how difficult it had previously been for man to hunt the rich fauna of the highest jungle levels, and how much he tended to concentrate on the terrestrial and lower arboreal.

Nevertheless, there is much to show that through Borneo iron produced a technological acceleration rather than a "revolution": that to a large extent it was adapted to and within the continuing framework of emerging advances in Neolithic thinking and social organization, with a population rapidly expanding before iron appeared. In this connection one must emphasize that quite recent explorations in Central New Guinea have shown nearly a million people living with a highly developed culture and irrigated agriculture, above the 3,000-foot mark there, strictly in the stone age.

By now (1965) it may have become almost painfully clear, to those who have been patient enough to follow my thesis so far, that both the Borneo present and the Borneo past are exceedingly complex; if we are ever to understand them we must use archeology in parallel with folklore—and also, of course, ethnology, anthropology, and linguistics. But I do not for a moment wish to imply that the task is too difficult to be undertaken. On the contrary, it can be very rewarding. For there is, I think, a better chance of getting a full picture for Borneo than perhaps anywhere else in far Asia. Conditions that encouraged active and extending fieldwork since 1947 continue into 1965. There are, of course, grave political difficulties as between Indonesia and Malaysia. But it is an ethnic fact that nearly all the major groups of island population are represented on both sides of the political border and that a large part of the total picture can be built up from one side. Later, under happier conditions, the rest can be filled in from the other. One great thing about archeology is that it can nearly always wait. A pressing urgency about folklore is that in emergent new nations it is liable to be lost unless immediately recorded for future generations.

Let me now concentrate on the archeological aspect more strictly.

From 1947 on, the Sarawak Museum began to train local staff in excavating techniques, beginning with simple work at the early iron age sites in the Sarawak River delta already referred to and in some small caves at Bau, close to the Museum in the capital at Kuching. Some of the results of this earlier work have been published in the *Journal of the Polynesian Society*, and fairly extensively in the *Sarawak Museum Journal.* This latter journal, in which we have pro-

duced 4,000 pages of original work since 1947, has also dealt extensively with the more elaborate excavations which we have gradually developed, particularly at the Niah caves, with personnel trained on the lesser sites. Three papers have appeared in *Man*, but I am only too conscious of the fact that we have been so much engaged with the work itself that we have tended to publish only locally. Nevertheless, the material which I will now seek to summarize is largely available in that print, including papers by foreign experts who have generously assisted our project by studying material sent to them from Sarawak, notably Dr. D. A. Hooijer and Professor G. H. R. von Koenigswald from Holland; Dr. D. Brothwell, the Earl of Cranbrook, Miss Mary Tregear, Professor S. Tratman, and Dr. Calvin Wells in Britain; Dr. Robert Griffing, Dr. R. Kerr, Dr. A. R. Griswold, Dr. W. S. Solheim and Dr. Robert Inger from the U.S.A. This is also the moment to express warm thanks to the Calouste Gulbenkian Foundation, who have made a series of very generous grants to the work; to the Shell Group of companies and the Chicago Natural History Museum, who have supported us in many ways in the field; and to the Sarawak government for its continuing basic support. We have also had encouragement and good advice from Sir Wilfrid Le Gros Clark, F.R.S., Dr. Kenneth Oakley, F.B.A., Dr. M. Burkitt, Dr. Richard Shutler, and Professor W. W. Howells. Most of these mentioned above have come to see our work on the spot.

We began digging at Niah in 1954, by which time I had enough trained staff and some initial financial support. By then we already knew that the Great Cave covered over 25 acres. The first trial trench, dug with Mr. Michael Tweedie and Mr. Hugh Gibb, showed rich human materials under a surface which indicated nothing. I have traced, in the *Sarawak Museum Journal* for 1958, the strange story of early searches in this cave, the first inspired by the great Alfred Russel Wallace—who spent more than a year in Sarawak just over a century ago and focused attention on the search for a Borneo "missing link." I have also there explained how this vast cavern with more than 2 million edible bird's-nest swiftlets and nearly half a million bats (of seven species), was lost to human knowledge and exploitation for several centuries after the collapse of the China–Borneo trade in the Ming dynasty; how it was rediscovered by nomadic Punans, and again became a socioeconomic center, first as a major source of bird's-nests, and subsequently of bat guano for fertilizer. But the swiftlets and bats live in the dark bowels of the caves, which through various chambers run for miles through the Niah mountain.

The main or west mouth of the Great Cave is about 200 yards wide and up to 100 yards high. This is so light that it is free of guano, and thus remained untouched until 1954. After initially proving the site in 1954, it took some time to raise the large additional funds and out-

side help that were clearly going to be necessary, but in 1957 we started large-scale regular excavation. Now, in 1963, we have a house inside the cave, mouth and a large base camp organization on the river 2 miles away, with a connecting hardwood plank-walk from river to cave. Permanent staff are on duty all the year round. We average 4 to 5 months' field excavation during the year; and all-the-year-round analysis back in Kuching (where we now have a fine new research building).

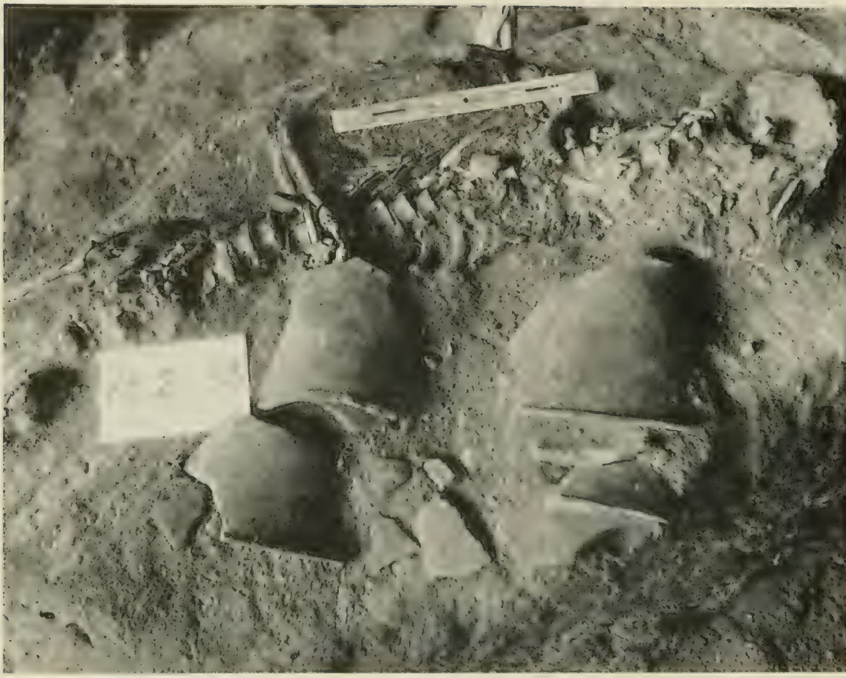
The simplest fact about the Great Cave west mouth is that what appears to be earth producing a wide pleasant floor is really almost solid human deposit, back at least into the middle Paleolithic. The outer part of the mouth was used primarily for frequentation in the Neolithic—by which time people were making some permanent dwellings out in the rain forest; and for regular habitation in the earlier phases of stone age (Paleolithic–Mesolithic).

In front of the guano belt of darkness, the whole floor is netted with burials, of which we have now more than 100 left exposed in situ, under perspex covers—for later full study. Burials also occur in the habitation-frequentation zone, mostly at the deeper levels; usually the bodies distorted, crouched, or the head alone. The deepest of these so far is a young *Homo sapiens* boy which has been fully published by Dr. Brothwell and generally accepted (e.g., at the recent Pacific Science Congress, Hawaii) as corresponding to a carbon-14-dated level of around 38,000 B.C. There is good reason to believe that its date is correct within, at the worst, a few thousand years; and it therefore represents much the earliest *Homo sapiens* ("modern man") found so far East. The further inferences is that *Homo sapiens* was much more widely distributed considerably earlier than has previously been supposed. This is indirectly supported by other archeological indications that human culture advanced early and rapidly in West Borneo. I believe that full excavation elsewhere in Southeast Asia will undoubtedly provide similar material in Malaya, Thailand, and Indonesia. Dr. Robert Fox (of the National Museum in Manila) and I visited Palawan in the Southern Philippines 2 years ago, on an archeological reconnaissance, and he has since, using similar techniques there, already produced *Homo sapiens* material which is datable to beyond 20,000 B.C. from a Palawan cave.

The Brothwell Niah skull comes from 100 inches level in the West Mouth excavations at a pit we call "Hell"—owing to the heat and discomfort of working there . . . The deposit down here is extremely fine and difficult to work. Soon after 100 inches, bone (both human or food remains) and all food shell (of which 20 species occur in quantity higher up) disintegrate completely through the mere process of equatorial time. For a feature of Niah is that nothing in these deposits has fossilized. Under the peculiar conditions of this great limestone

1. Sarawak Museum's laboratory inside Niah Great Cave mouth. Edible birdsnest climbing poles are shown on each side of the hut, rising from a declivity in the background.

2. General view up main excavation area in West Mouth, Niah Great Cave. "Cemetery" is at far back; main "frequentation" area is in foreground.



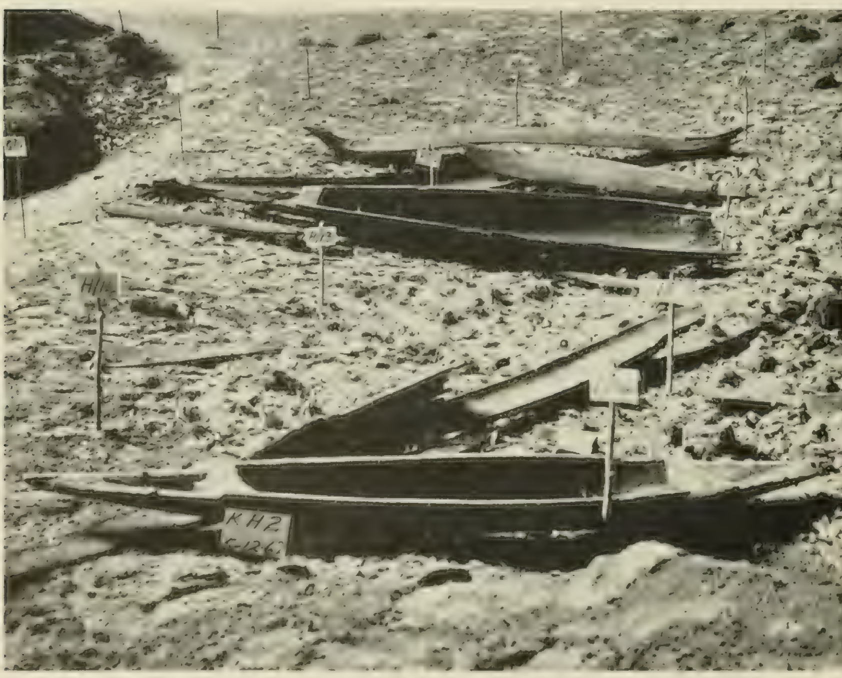
1. Neolithic burial (No. 76) at Niah Great Cave, with associated pottery.

2. Massive earthenware urn, decorated in three colors and used for "secondary burials," especially of women and babies, in the late Neolithic of West Borneo.

1. Working below the 100-inch layer—on which the author is standing—in "Hell" at c. 40,000 B.C. in Niah Great Cave.

2. The Deep Skull, from Niah—earliest *Homo sapiens* known in Far Asia.

1. Wall paintings in scarlet haematite, Painted Cave, Niah. A major emphasis is on "death ships."



2. "Death ship" coffins lying on floor of Painted Cave, Niah.

cave, it has been so naturally and slowly dehydrated that bone and shell simply continue until they expire.

Below 120 inches—and we are now working well below this—the main indications of human activity are through chemical analyses of the "soil" (which have been undertaken for us by Dr. C. A. Sutton and others), by certain pollens (on which we have been working with the Shell laboratories), and by the presence of stone tools and fire strikers.

Stone tools are, of course, the clearest indication of all. But here we come up against another peculiarity of Niah and West Borneo generally. There is a great shortage of durable, workable stone throughout the area—even of rough stone suitable for roadmaking. Whereas in Sabah, Malayan, Thai, and Palawan caves large quantities of stone tools are generally found, all through West Borneo hard stone has been sparse, and was clearly precious to early man. At the deeper levels we are finding only very small, fine flakes of quartzite. Even in the late Neolithic, when there was clearly much mobility and even sea traffic, the polished stone tools are quite few and far between in the excavation. By presistence over the years, we have now acquired a good series for the whole deposit. But it is not unusual, with a team of up to 50 or so working, to recover no more than one stone tool during the day. Correspondingly, there has been an elaboration of bone tools, on which Lord Medway and I have recently published a first attempt at an 18-category typology.

It is quite possible that as we continue lower at Niah we shall come to a level of true fossilization; or, anyway, limification. Otherwise, we have little chance of finding pre-*Homo* skeletal remains such as *Pithecanthropus*. We may now reach that sort of depth by 1965. Meanwhile, common sense suggests that such early hominids were present in Borneo, which had a land link with Java and "Java men" in the Pleistocene. We have recently recovered, in a bauxite mine near Kuching, two large stone tools which may well belong to that "culture," as described by Dr. von Koenigswald and Dubois.

Of particular interest in this connection is the presence, in the "Hell" deposit at Niah, of the extinct giant pangolin, *Mainis palaeojavanica* (Dubois). This was previously described from the fossil beds of Trinil in Java associated with *Pithecanthropus*. The curator of the Dubois Collection at Leyden, Dr. Hooijer, has now identified from Niah a series of bones of this huge, scaly anteater—in of course non-fossil condition—extending to the limit of our bone survival depth in "Hell." It has not been found in the high levels.

In the higher levels, for which we have a series of published carbon-14 dates, and others in preparation, I very provisionally put forward the crude tabulation shown in table 1.

TABLE 1.—*Preliminary Niah phascology*

Phase	Main "characteristic"	Approximate Niah starting date (estimated)
1. Middle Paleolithic?	Tiny flakes	40,000+B.C.
2. -----do	"Mid-Sohan" flake [1]	35–40,000 B.C.
3. Upper Paleolithic?	Chopping tools and large flakes	ca. 30,000 B.C.
4. -----do	Small flakes	25–30,000 B.C.
5. "Paleo–Mesolithic"?	"Advanced flakes"	10,000 B.C.?
6. "Mesolithic"	Edge-ground tools	ca. 7,000 B.C.
7. Neolithic	"Round ax"	ca. 4,000 B.C. (or later).
8. -----do	Quadrangular adzes; fine pottery, jewelry, mats, nets, etc.	ca. 250 B.C.
9. "Chalcolithic"	"Soft tool" in stone; slight nonfunctional bronze; elaborate pottery, beads.	ca. 250 B.C.
10. Early iron	Iron tools, imported ceramics, *glass* beads, etc.	A.D. 650 (until A.D. 1300).

[1] *See* Man, 1959.

I should emphasize the apparent absence (at No. 6 in table 1) of those distinctive struck pebble tools usually attributed to the Mesolithic in Malaya and Indonesia and name "Hoabinhian" after the type site in Vietnam. I am mildly sceptical about the "Hoabinhian" as generally accepted; in any case, it is—as at present defined—strikingly absent at Niah.

The situation at Niah is not, clearly, unique. Further cave exploration in Borneo will surely yield similar results. But there are certain conditions that are desirable to produce a site of this richness. For one thing, a cave floor must be well above sea level, to avoid effects of prehistorical changes in level and also massive floods from the great rivers—which have continued even in historical times. It was also a big attraction to early man to have a cave literally teeming with protein in the form of edible birds and bats.

Yet the extent to which a place like Niah became a center of stone age civilization has only been barely indicated above. As well as the work in the West Mouth, in the last 5 years we have been exploring the whole limestone formation of the Niah massif. We have found literally scores of other caves of archeological value. One of these, first identified from the air, involved a group of skilled climbers in 5 days' preparation and ladder building before they could reach it high up in the cliff. It proved to be a cave almost as impressive as the West Mouth itself; and a first scratch at the surface produced positive human results. We have so far excavated extensively in 5 other

caves in the formation. The broad results fit with the West Mouth picture: But in every case something new and special has appeared as well—including some evidence for a small Neolithic "negritoid" population living alongside larger people, but using separate burial caves (there have been no negritos on the island in historic times).

Most exciting of all is a beautiful cave 300 ft. up in a difficult cliff, the whole back wall of which is painted with primitive designs in scarlet hematite. The cave floor is littered with relics of late stone and early iron age rituals for secondary burial (transference of bones) and the journey of the dead, including quantities of early Chinese porcelain and other mainland imports. A separate monograph on this cave is now under preparation.

This "Painted Cave" showed no sign of having been visited by man during several centuries. It is too high and light to contain either of Niah's modern incentives for search—bat guano or edible nests. After reconstructing, by excavation in association with the wall paintings, a picture of what we think was going on there about a thousand and more years ago, we found that some of the same ideas were present in the folklore and custom of the Punans living at Niah today. They themselves became so interested in this that, with the help of some of the oldest men, we have been able to "revive" the old Punan death rites for secondary burial to assist the spirits in the journey of the dead. This clearly goes right back into the ancient past—and now it can be shown in film.

On the whole, the most striking impression gained from all this work is of the highly advanced culture that was achieved as the stone age proceeded in West Borneo. By the later Neolithic, say at 2,000 B.C., there were beautifully made polished tools, superb pottery decorated in three colors, of which we now have reconstructed or whole pieces and over 200,000 classified sherds. They had an elaboration of shell, bone, and stone jewelry (including jade); mats, nets, and good boats. They showed what could fairly be described as a love of the dead, extending not only to exquisitely laid out primary burials, but also to secondary burial and cremation, especially of babies—these long predating the Hindu influence to which this custom had hitherto been attributed in Southeast Asia.[4] They had a small domestic dog, possibly a Neolithic lap dog rather than a hunter—as proved by bones not only from Niah but from 400 miles away behind Kuching. This dog features in folklore but is now extinct, completely swamped by the only too familiar bigger "pye dog" of the East, which iself is related to the Basenji breed of sophisticated dog breeders.

This dynamic Neolithic undoubtedly extended far inland into the central highlands; and along the coast even to tiny offshore islands.

[4] For a fuller account of the growth and elaboration of contemporary death rites out of the stone age, see "Borneo Death," *Bijdragen*, vol. 116. Leiden. 1962.

Recently, the Sabah Government was faced with the necessity of blowing up a whole islet to get "fill" for the extension of the airport of Labuan, for this was the only hard stone anywhere near. In the process the engineers came across a tiny cave. A Sarawak Museum unit was rushed up there; and we were able to recover what remained before the work of necessary destruction proceeded. On this one of many small islands, in a cave hardly big enough for three bodies, lay secondary burials associated with a three-color ware pottery and polished stone tools. This is just one clue to the scale and extent of human probing, that long ago.

Borneo has an astonishingly rich, varying, and enterprising culture today.[5] I think that the part which Sabah and Sarawak are going to play in the new Federation of Malaysia will amply demonstrate this in the most modern of settings. A good deal of the strength in this setup derives directly from a tremendous tradition of development and human evolution going right back to the Brothwell skull—and behind that.

This is, necessarily, both a general report and a preliminary one. Within a few months, I hope to be back working at Niah for at least another 2 years. Meanwhile, also, we are training local personnel to extend these investigations more widely in Malaysian Borneo and the State of Brunei. We should welcome further outside support, particularly from specialists prepared to collaborate on specific sections of the project, whether out there or back here in the West..

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[5] For a picture of living cultures inside Borneo, see the 1963 Dickson Asia Lecture to the Royal Geographical Society in *Geographical Journal*, 1964. The megalithic culture and past population of the uplands are also discused there.

The Emergence of the Plains Indian as the Symbol of the North American Indian

By John C. Ewers

Director, Museum of History and Technology
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[With 18 plates]

One summer's day in 1941 I stood on the North Montana Fairground in Great Falls. From a stand in front of me a fast-talking patent medicine salesman was vigorously extolling the curative powers of his bottled wares. From time to time he pointed to the living advertisement standing beside him—a tall, erect, young White man whose paint-streaked face was framed by a beautiful, flowing-feather bonnet. The young man's body was clothed in a cloth shirt, leggings, and a breechclout dyed to resemble buckskin. His feet were clad in beaded moccasins. The audience, for the most part, was composed of Indians from Montana reservations wearing common White men's clothes—shirts and trousers. I was intrigued by the fact that this pale-faced symbol of an American Indian standing before us was wearing a close approximation of the same costume the Blackfeet, Crees, and Crows in the audience would put on when they staged an Indian show for the enjoyment of tourists.

How did this picturesque costume come to symbolize "Indianness" to the minds of Indians and Whites alike? How did the popular image of the Indian come to be formed in a Plains Indian mold? Why do people in Europe and America, when they think of Indians, tend to think of them as wearers of backswept feather bonnets, as dwellers in conical tipis, and as mounted warriors and buffalo hunters? Surely our founding fathers had no such conception of the Indian in the days when the frontier of settlement extended only a short distance west of the Alleghenies, and the only Indians the remote frontiersmen knew were forest dwellers who lived in bark-covered houses, traveled in bark canoes or dugouts, hunted and fought on foot, and wore no flowing-feather bonnets. Nor was the prevailing popular image of the Indian an original creation of the motion pictures during the 20th century. How and when, then, did this image emerge?

Probing into history we find that the creation and clarification of this image was a prolonged process to which many factors contributed. Let us try to trace the development of this image from what appear to be its earliest beginnings.

THE FIRST PICTURES OF PLAINS INDIANS (1804–1840)

Obviously before non-Indians could begin to picture Indians in Plains Indian terms, they had to have fairly clear ideas of the appearance of the Indians of the Great Plains and of those aspects of their culture that typified their way of life. European explorers and traders traversed considerable portions of the Plains in the 2½ centuries between Coronado's quest for the fabled city of Quivera on the grasslands of Kansas in 1541 and the purchase of Louisiana by the United States in 1803. Nevertheless, those Spaniards, French, and Englishmen produced no popular literature about and no known pictures of Plains Indians—either portraits or scenes of Indian life. At the time of the Louisiana Purchase these Indians remained virtually unknown to the peoples of Europe and the United States (although a number of earlier explorers' and traders' accounts have been published since that time).

The earliest known portraits of Plains Indians were made in the cities of the East during the first decade of the 19th century. They were likenesses of Indians whom President Jefferson urged Lewis and Clark to send to the seat of government in Washington. They were profiles executed by two very competent artists, who both employed versions of a mechanical device, known as a physiognotrace, to accurately delineate the outlines of their sitters' heads. The French refugee artist Charles Balthazer Fevret de Saint-Mémin made portraits of some of the 12 men and 2 boys of the Osages who comprised the first delegation of Indians from beyond the Mississippi. Thomas Jefferson welcomed these Indians to the Presidential Mansion in the summer of 1804, and enthusiastically termed them "the most gigantic" and "the finest men we have ever seen" (Jackson, 1962, p. 199). Saint-Mémin's most striking profile is that of the chief of the Little Osages (pl. 1, fig. 1).

Charles Willson Peale, prominent Philadelphia artist and museum proprietor, cut miniature silhouettes of 10 members of a second Indian delegation from the West. He sent a set of these profiles to President Jefferson on February 8, 1806 (Jackson, 1962, p. 299). One of these sitters was Pagesgata, a young Republican Pawnee from the Platte Valley (pl. 1, fig. 2).

After his return from the Pacific coast, Meriwether Lewis purchased several originals or copies of Saint-Mémin's Indian portraits. Undoubtedly he intended to reproduce them in an elaborately illustrated account of the Lewis and Clark explorations which he proposed, but

never produced because of his untimely death in 1809. Peale also was to have furnished illustrations for this ill-fated work. Doubtless they would have included accurate drawings of the Plains Indian costumes and other artifacts sent or brought back by Lewis and Clark, which Peale exhibited in his popular Philadelphia Museum.

More significant factors in the early diffusion of the Plains Indian image were the oil portraits of several members of an Indian delegation from the Lower Missouri and Platte Valley tribes who arrived in Washington late in the year 1821. Although Charles Bird King painted these Indians for Thomas McKenney, Superintendent of Indian Trade, he executed several replicas of these paintings that were diffused more widely—one set being sent to Denmark, another to London. The original portraits formed the nucleus of the National Indian Portrait Gallery, which became one of Washington's popular tourist attractions before it was almost completely destroyed in the Smithsonian Institution fire of 1865 (Ewers, 1954).

The most popular Indian in that 1821 delegation was Petalesharro, a young Pawnee warrior. He was hailed as a hero during his eastern tour because he had courageously rescued a Comanche girl captive just as her life was to be taken in the traditional human sacrifice to the morning star, an annual Pawnee ceremony. Petalesharro's portrait was painted by John Neagle in Philadelphia, as well as by King, and Samuel F. B. Morse placed him in front of the visitor's gallery in his well-known painting of "The Old House of Representatives," executed in 1822. (See pl. 2.) All three paintings show this Indian hero wearing a flowing-feather bonnet. They are, to the best of my knowledge, the first of the millions of pictorial renderings of this picturesque Indian headgear produced by artists and photographers.

The popular novelist James Fenimore Cooper met Petalesharro during that Indian's eastern tour. This meeting was a source of inspiration to the author in writing *The Prairie*, the only one of the *Leatherstocking Tales* to have a Great Plains setting (Keiser, 1933, pp. 134–138). In the living Indians of the Plains, Cooper recognized the virtues he had imputed to his Woodland Indian heroes of an earlier period in *The Last of the Mohicans*. Writing of the Indians 2 years after that popular novel was published, he observed: "The majority of them, in or near the settlements, are an humbled and much degraded race. As you recede from the Mississippi, the finer traits of savage life become visible."

Cooper thought that Plains Indian chiefs possessed a "loftiness of spirit, of bearing and of savage heroism . . . that might embarrass the fertility of the richest inventor to equal," and he cited Petalesharro as a prime example (Cooper, 1828, vol. 2, pp. 287–288).

Some of the distinctive traits of the Plains Indians were pictured in illustrated books and magazines prior to 1840. The first published

picture of the conical skin-covered tipis of the nomadic Plains tribes was a crude engraving after Titian Peale's field sketch on Major Long's expedition of 1819–20, which appeared in Edwin James' account of those explorations (James, 1823). (See pl. 3, fig. 1.) The first reproduction of a Plains Indian warrior on horseback probably was the lithograph of Peter Rindisbacher's drawing "Sioux Warrior Charging" that appeared in the October 1829 issue of *The American Turf Register and Sporting Magazine* (pl. 4). Young Rindisbacher had ample opportunities to observe Plains Indian warriors and buffalo hunters during nearly 5 years' residence in Lord Selkirk's settlement on the Red River of the North, 1821–26. His lively portrayal of Indians on horseback chasing buffalo was offered as the colored lithographic frontispiece in the first volume of Thomas McKenney and James Hall's classic *History of the Indian Tribes of North America* (1836–44). (See pl. 5.) However, of the 120 finely printed colored lithographs of Indians in that handsome work only a small proportion portray Plains Indians, and all of these were portraits of members of western delegations to Washington, the originals of which had been executed by Saint-Mémin, King, or the latter's pupil George Cooke.

In 1839 Samuel George Morton of Philadelphia, now known as the father of physical anthropology in America, published his major work, *Crania Americana.* Its frontispiece is a lithographic reproduction of John Neagle's portrait of the Omaha head chief Big Elk, a prominent member of the 1821 deputation from the Great Plains. Morton explained this selection: "Among the multitude of Indian portraits which have come under my notice, I know of no one that embraces more characteristic traits than this, as seen in the retreating forehead, the low brow, the dull and seemingly unobservant eye, the large aquiline nose, the high cheek bones, full mouth and chin and angular face" (Morton, 1839, p. 292). (See pl. 3, fig. 2.)

The first illustrated schoolbook on American history was Rev. Charles A. Goodrich's *History of the United States.* First published in 1823, it went through 150 printings by 1847. However, Noah Webster's *History of the United States* was a popular competitor from its first appearance in 1832. The small and sometimes indistinct woodcuts in these books are not numerous. Nevertheless, some of them include Indians. A few scenes in Webster's history were adopted from John White's 16th-century drawings of Indian life in coastal North Carolina. But the scenes depicting early explorers' meetings with Indians, the making of Indian treaties, and the conduct of Indian wars seem to be based largely upon the imaginations of their anonymous creators. Plains Indians are conspicuously absent. They had yet to make an indelible mark upon American history in their determined

resistence to the expansion of White settlement onto and across their grassy homeland.

THE INFLUENCE OF GEORGE CATLIN AND KARL BODMER (1841–60)

No other mid-19th century factors had such a stimulating influence on both (1) the projection of the Plains Indian image and (2) the acceptance of this image as that of the American Indian par excellence as did the writings of the American artist George Catlin and the German scientist Maximilian Alexander Philipp, Prince of Wied-Neuwied; and the pictures of Catlin and of the Swiss artist Karl Bodmer, who accompanied the prince on his exploration of the Upper Missouri in 1833–34.

Inspired by the site of a delegation of western Indians passing through Philadelphia on their way to Washington, and his own conviction that the picturesque Plains Indians were doomed to cultural extinction as the frontier expanded westward, Catlin determined to rescue these Indians from oblivion and to "become their historian" before it was too late. During the summers of 1832 and 1834 he traveled among the tribes of the Upper Missouri and the Southern Plains gathering information and preparing pictures for an Indian Gallery, which he exhibited to enthusiastic audiences in the larger American cities. In 1840, he took the exhibition to England for a 4-year display in London; this was followed by a Paris exhibition that included a special showing for King Louis Philippe in the Louvre. In addition to his paintings this exhibition included costumed mannequins, a pitched Crow tipi, and enactments of Indian dances and ceremonies by Chippewa or Iowa Indians. No one had brought the Wild West to civilization as had Catlin, and his exhibition must have made a lasting impression upon all Americans and Europeans who saw it.

Nevertheless, Catlin's books must have had a still wider influence. His two-volume *Manners, Customs and Condition of the North American Indians*, published in London in 1841, combined a vivid description of his travels and observations with 312 steel-engraved reproductions of his paintings. The work was enthusiastically reviewed in America and abroad, and was reprinted five times in as many years. Although Catlin included brief descriptions and illustrations, primarily portraits, of a number of the semicivilized Woodland tribes, he concentrated primarily upon the wild tribes of the Great Plains. There could be no mistaking either from his text or from his pictures that the Plains Indians were his favorites. Repeatedly, if not consistently, Catlin sang their praises. He declared that the tribes of the Upper Missouri were the "finest specimens of Indians on the Continent . . . all entirely in the state of primitive rudeness and wildness, and consequently are picturesque and handsome, almost beyond

description." The Crows were as "handsome and well-formed set of men as can be seen in any part of the world"; the Assiniboins "a fine and noble looking race." There were no "finer looking men than the Sioux"; and Catlin used almost the same words to describe the Cheyennes. (Catlin, 1841, vol. 1, pp. 22–23, 49, 54, 210; vol. 2, p. 2.) Catlin devoted several chapters of his book to Four Bears, the second chief of the Mandan, whom he called the "most extraordinary man, perhaps, who lives to this day, in the atmosphere of Nature's noblemen." (See pl. 6, fig. 1.)

Prince Maximilian's *Reise in das Innere Nord-America in den Jahren 1832 bis 1834*, first published in Coblenz (1839–41), offered a more restrained, scientific description of the Indians of the Upper Missouri. Nevertheless, it was reprinted in Paris and London within 3 years, and the demand for it soon exceeded the supply. Its great popularity was due largely to the excellent reproductions of Karl Bodmer's incomparable field sketches of Plains Indians that appeared in the accompanying *Atlas*.

Together the works of Catlin and Maximilian-Bodmer, appearing almost simultaneously, greatly stimulated popular interest in the Plains Indians in this country and abroad, and had a strong influence on the work of many other artists.

They influenced the pictorial representation of Indians during the mid-19th century in three important ways. First, the Catlin-Maximilian-Bodmer example encouraged other artists to go west and to draw and/or paint the Indians of the Plains in the field. Among the best known of these artists were the American John Mix Stanley, the German-American Charles Wimar, the Canadian Paul Kane, and the Swiss Rudolph Friederich Kurz.

Secondly, they encouraged some of the most able illustrators of the period, who had not visited the western Indian Country, to help meet the popular demand for pictures of Plains Indians by using the works of Catlin and Bodmer for reference. In 1843, 2 years after the first publication of Catlin's popular book, an enterprising Philadelphia publisher offered *Scenes in Indian Life: A Series of Original Designs Portraying Events in the Life of an Indian Chief. Drawn and etched on Stone by Felix O. C. Darley.* This pictures episodes in the life history of a fictional Sioux chief. The artist was then an almost unknown "local boy," 20 years of age; but he possessed remarkable skill as a draftsman. Darley became the outstanding American book and magazine illustrator of the century. Even though most of his finely drawn illustrations are of non-Indian subjects, he repeatedly pictures buffalo hunts and other Plains Indian activities. He prepared the frontispiece and illustrated title page for the first edition of Francis Parkman's classic, *The California and Oregon Trail* (1849), and toward the end of his life designed a colored lithograph, "Return from the Hunt," which has the qualities of spurious realism that only a

highly skilled artist who does not know his subject can impart to his work. The picture shows a birchbark canoe in the foreground, a village of tipis in the middle ground, and a background of high mountains. Darley appears to have produced a handsome geographical and cultural monstrosity in which characteristics of the region from the Great Lakes to the Rocky Mountains are compressed into a single scene (pl. 9).

Darley was on firmer ground when he followed Catlin and Bodmer more closely. A few of his book illustrations are frankly acknowledged as "after Catlin" (pl. 8).

Some of the most popular Currier and Ives prints of the 1850's and 1860's were western scenes, lithographed from very realistic drawings executed jointly by German-born Louis Maurer and English-born Arthur Fitzwilliam Tait, neither of whom had any first-hand knowledge of Plains Indians. Maurer acknowledged that they learned about Indians from the reproductions of Bodmer's and Catlin's works in the Astor Library in New York City (Peters, 1931, p. 21).

Finally Catlin and Bodmer powerfully influenced those lesser, poorly paid artists who anonymously illustrated a number of popular books on Indians as well as school histories; these began to appear within a very few years after the books of Catlin and Bodmer were published. One can trace the progressive degeneration of truthfulness in illustration in the copies of these once popular books preserved in the Rare Book Room of the Library of Congress.

A prolific writer of popular books of the 1840–60 period was Samuel Griswold Goodrich, who commonly used the pen name "Peter Parley," and who claimed in 1856 that he had written 170 books of which 7 million copies had been sold. Goodrich had discovered Catlin by 1844, when he published *History of the Indians of North and South America;* he quoted Catlin in the text and copied Catlin's "Four Bears" in one illustration. Two years later Goodrich's *The Manners, Customs, and Antiquities of the Indians of North America* derived all of its 35 illustrations of North American Indians from Catlin—28 of these being Plains Indian subjects. Finally, in Goodrich's *The American Child's Pictorial History of the United States*, first published in 1860, and adopted as a textbook for the public schools of Maryland 5 years later, the Indians of New England, Virginia, and Roanoke Island are pictured living in tipis and wearing flowing-feather bonnets of Plains Indian type, while 17th-century Indians of Virginia are shown wrapped in painted buffalo robes and performing a buffalo dance in front of their tipis.

Impressionable young readers of popular histories of the Indian wars published in the 1850's also saw the common traits of Plains Indian culture applied to the Woodland tribes. John Frost's *Indian Wars of the United States from the Earliest Period to the Present*

Time pictures a buffalo hunt on horseback in the chapter on the French and Indian Wars, Catlin's Crow warrior on horseback in the one on the War of 1812, and the same artist's portrait of Eagle Ribs, a Blackfoot warrior, in the Creek war chapter.

Catlin's and Bodmer's representations of Plains Indians underwent even more miraculous changes in identity in William V. Moore's *Indian Wars of the United States from the Discovery to the Present Time.* In that book Catlin's "Four Bears" became "Pontiac" (pl. 6, fig. 2), his Crow Indian on horseback "A Creek Warrior" (pl. 7, fig. 2), and a ceremonial in a Mandan setting emerged as "Village of the Seminoles." Bodmer's well-identified portraits of Mandan, Hidatsa, and Sioux leaders became "Saturiouva," a 16th-century Florida chief, and two leaders in the Indian wars of colonial New England.

The first illustrated edition of Henry Wadsworth Longfellow's popular *Song of Hiawatha* was published in England in 1856. John Gilbert, its illustrator, did not copy Catlin slavishly but leaned heavily upon him in representing the poet's ancient Ojibwa of the southern shore of Lake Superior as typical Indians of the Upper Missouri. His portrait of "Paw-puk-keewis," for example, is but a slightly altered version of Catlin's Mandan hero, "Four Bears" (pl. 6, fig. 3).

Nor were these Woodland Indians in Plains Indian clothing limited to the works of artists who had had no first-hand knowledge of Indians. John Mix Stanley had known the Plains tribes well, yet when he attempted a portrait of "Young Uncas" (the 17th-century Mohegan) or "The Trial of Red Jacket" (the Seneca), he tended to clothe his Indians in the dress costume of the tribes of the western grasslands (pl. 10). And when Karl Bodmer collaborated with the French artist Jean François Millet to produce a series of realistic but imaginative scenes in the border warfare of the Ohio Valley during the Revolutionary War, the war-bonneted Plains Indian was clearly portrayed (Smith, 1910, p. 83).

INFLUENCE OF THE PLAINS INDIAN WARS (1860–90)

In 1860 a new medium appeared to exploit the American boy's fascination for the Indian's prowess as a warrior. Dime novels increased very rapidly in both numbers and sales. A favorite theme in this lurid literature was Indian fighting on the Western Plains in which many a wild Comanche, Kiowa, Blackfoot, or Sioux "bit the dust" before the hero ended his perilous adventures. Bales of these cheap "paperbacks" were sent to the soldiers in camp or in the field during the Civil War, and reading them helped the boys in blue or gray to forget, for a time at least, their own hardships and sufferings (Johannsen, vol. 1, p. 39).

The horrors of Plains Indian warfare became very real as emigrants, prospectors, stage, and telegraph and railroad lines pushed across the

Plains after the Civil War, and the Sioux, Cheyenne, Arapaho, Kiowa, and Comanche resisted White invasion of their buffalo hunting grounds. Newspaper and magazine reporters were sent West to report the resultant Indian wars. Theodore R. Davis, artist-reporter for *Harper's Weekly*, was riding in a Butterfield Overland Dispatch Coach when it was attacked by Cheyennes near the Smoky Hill Spring stage station on November 24, 1865. His vivid picture of this real-life experience, published in *Harper's Weekly*, April 21, 1866, was the prototype of one of the most enduring symbols of the Wild West—the Indian attack on the overland stage (pl. 11).

As the Indians of the Plains made their desperate last stand against the Army of the United States they again and again demonstrated their courage and skill as warriors. On the Little Bighorn, June 26, 1876, they wiped out Custer's immediate command in the most decisive defeat for American arms in our long history. Numerous artists, largely upon the basis of their imaginations, sought to picture that dramatic action. One pictorial reconstruction of a closing stage of this battle, Otto Becker's lithograph "Custer's Last Fight," after Cassilly Adams' painting, has become one of the best-known American pictures. Copyrighted by Anheuser-Busch in 1896, more than 150,000 copies of this large print have been distributed. It has provided a lively conversation piece for millions of customers in thousands of barrooms throughout the country (Taft, 1953, pp. 142–148). (See pl. 12.)

Four years before his death, George Armstrong Custer published serially in the *Galaxy*, a respectable middle-class magazine, "My Life on the Plains," in which he expressed his admiration for "the fearless hunter, matchless horseman and warrior of the Plains." Many Army officers who had fought against these Indians expressed similar opinions in widely read books on their experiences, some of which were profusely illustrated with reproductions of drawings and photographs, including portraits of many of the leading chiefs and warriors among the hostiles—Red Cloud, Satanta, Gaul, Sitting Bull, and others. The exploits of these leaders on the warpath became better known to late 19th-century readers than those of such earlier Indian heroes of the forest as King Philip, Pontiac, Tecumseh, Osceola, and Black Hawk.

THE WILD WEST SHOW AND ITS INFLUENCES (1883–)

On July 20, 1881, Sitting Bull, the last of the prominent Indian leaders in the Plains Indian wars to surrender his rifle, returned from his Canadian exile and gave himself up to the authorities of the United States. But within 2 years William F. Cody, pony express rider, scout, Indian fighter, and hero of hundreds of dime novels, whose hunting skill had earned him the name "Buffalo Bill," organized a

reenactment of exciting episodes of the Old West that was so realistic no one who ever saw it could forget it. Buffalo Bill's Wild West Show opened in Omaha, Nebr., on May 17, 1883. It ran for more than three decades, before millions of wide-eyed viewers in the cities and towns of the United States and Canada; in England; and on the continent of Europe. Sitting Bull himself traveled with the show in 1885. It always included a series of performances staged in the open by genuine Plains Indians—Pawnees, Sioux, Cheyennes, and/or Arapahoes—chasing a small herd of buffalo, war dancing, horse racing, attacking a settler's cabin and/or an emigrant train crossing the Plains. A highlight of every performance was the Indian attack on the Deadwood Mail Coach, whose passengers were rescued in the nick of time by "Buffalo Bill" himself and his hard-riding cowboys. This scene was commonly portrayed on the program covers and the posters advertising the show (pl. 13).

In 1887 this show was the hit of the American Exhibition at the celebration of Queen Victoria's Golden Jubilee in England, playing to packed audiences in a large arena that held 40,000 spectators. The *Illustrated London News* for April 16, 1887, tried to explain its fascination:

> This remarkable exhibition, the "Wild West," has created a furore in America, and the reason is easy to understand. It is not a circus, nor indeed is it acting at all, in a theatrical sense, but an exact reproduction of daily scenes in frontier life, as experienced and enacted by the very people who now form the "Wild West" Company.

Except in Spain, where no outdoor drama could quite replace the bullfight, Buffalo Bill's Wild West Show met with almost equal success on the European continent. During its 7 months' stand at the Paris Exposition of 1889 it attracted many artists. The famous French animal painter Rosa Bonheur pictured the show Indians chasing buffalo. What is more, the Indians inspired Cyrus Dallin, a gifted American sculptor then studying in Paris, to create the first of a series of heroic statues of Plains Indians. "The Signal of Peace," completed in time to win a medal at the Paris Salon of 1890, now stands in Lincoln Park, Chicago. A second work, "The Medicine Man" (1899), is in Fairmount Park, Philadelphia. The famous sculptor Lorado Taft considered it Dallin's "greatest achievement" and "one of the most notable and significant products of American sculpture" (pl. 14). Another, "The Appeal" (to the Great Spirit), winner of a gold medal at the Paris Salon of 1909, sits astride his horse in front of the Museum of Fine Art in Boston. And still a fourth, "The Scout," may be seen atop a hill in Kansas City. Taft termed Dallin's realistic equestrian Plains Indians "among the most interesting public monuments in the country" (Taft, 1925, pp. 476–8, 576).

The phenomenal success of Buffalo Bill's Wild West Show encouraged others to organize similar shows, which together with the small-scale Indian "medicine" shows toured the country and the Canadian Provinces in the early years of the present century, giving employment to many Indians who were not members of the Plains tribes. These shows played a definite role in diffusing such Plains Indian traits as the flowing-feather bonnet, the tipi, and the war dances of the Plains tribes to Indians who lived at very considerable distances from the Great Plains. A Cheyenne Indian who traveled with a medicine show is reputed to have introduced the "war bonnet" among the Indians of Cape Breton Island as early as the 1890's (Shaw, 1945, p. iv). Contacts with Plains Indian showmen at the Pan-American Exposition in Buffalo during 1901 encouraged New York State Seneca Indians to substitute the Plains type of feather bonnet for their traditional crown of upright feathers, and to learn to ride and dance like the Plains Indians so that they could obtain employment with the popular Indian shows of the period.[1] Carl Standing Deer, a professional sideshow and circus Indian, is credited with introducing the Plains Indian feather bonnet among his people, the Cherokee of North Carolina, in the fall of 1911.[2]

The acceptance of typical Plains Indian costume, of the tipi, and some other traits of Plains Indian culture as standard "show Indian" equipment by Indians of other culture areas is revealed through study of 20th-century pictures. My collection of photographic prints, post cards, and newspaper clippings dating from the turn of the century shows Penobscot Indians of Maine wearing typical Plains Indian garb (women as well as men), dancing in front of their tipis at an Indian celebration in Bangor; a Yuma Indian brass band in Arizona, every member of which wears a complete Plains Indian costume; dancing Zia Pueblo Indians of New Mexico wearing flowing-feather bonnets; Cayuse Indians of Oregon posing in typical Plains Indian garb in front of a tipi (pl. 15, fig. 1); and a young Indian standing in front of a tipi in the town of Cherokee, N.C., to attract picture-taking tourists and to lure them into an adjacent curio shop (pl. 15, fig. 2).

In 1958 I talked to a Mattaponi Indian in tidewater Virginia about the handsome Sioux-type feather bonnet he was wearing as he welcomed visitors to the little Indian museum on his reservation. He was proud of the fact that he had made it himself, even to beading the browband. With that simple and irrefutable logic which so often appears in Indian comments on American culture, he explained: "Your women

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[1] Communication from Dr. William N. Fenton, director, New York State Museum, June 12, 1964.

[2] Communication from John Witthoft, anthropologist, Pennsylvania Historical and Museum Commission, August 2, 1964.

copy their hats from Paris because they like them. We Indians use the styles of other tribes because we like them too."

The trend toward standardization in Indian costume based upon Plains Indian models has also been reflected in the art of some of the able painters of the Taos, N. Mex., art colony, for whom a sensitive interpretation of "Indianness" was more important than tribal consistency in detail. Likewise, it appears in prominently placed paintings purporting to commemorate significant historic events of the colonial period in the East. It is not difficult to recognize the Plains Indian costumes in Robert Reid's mural "Boston Tea Party," in the State House, Boston, or in Edward Trumbull's "William Penn's Treaty with the Indians" in the Capitol at Harrisburg, both of which were executed in the first quarter of this century. So perhaps it should not seem strange to see 19th-century Plains Indians sitting at the feast in Jennie Brownscombe's appealing painting "The First Thanksgiving," which hangs in Pilgrim Hall, Plymouth, Mass. (pl. 16).

THE PLAINS INDIAN AS A NATIONAL SYMBOL

It is a fact that every American coin bearing any resemblance to a representation of an Indian has strong Plains Indian associations. Both the Indian-head penny, first minted in 1859, and the $10 gold piece designed by Augustus Saint-Gaudens for issue in 1907 represent the artists' conceptions of the Goddess of Liberty wearing a feathered bonnet. A number of Indians have claimed they were the models for the fine Indian head on the famous "buffalo nickel." However, its designer, James Earle Fraser, in a letter to the Commissioner of Indian Affairs, dated June 10, 1931, stated: "I used three different heads: I remember two of the men, one was Irontail, the best Indian head I can remember; the other one was Two Moons, and the third I cannot recall."

Significantly, the two models remembered by the artist were Plains Indians. Two Moons, the Cheyenne chief, had helped to "rub out" Custer's force on the Little Big Horn. Strong-featured Iron Tail had repeatedly led the Sioux attack on the Deadwood Coach in Buffalo Bill's Wild West Show. (See pl. 17.) For 25 years after this coin was first minted in 1913—during the days when a nickel would purchase a ride on the New York subway, a cigar, or an ice-cream cone—this striking Indian head in association with the buffalo on the opposite side of the coin served to remind Americans of the Plains Indians.

The only regular issue United States stamp to bear the portrait of an Indian is the 14-cent stamp issued May 30, 1923. Titled "American Indian," it bears the likeness of Hollow Horn Bear, a handsome Sioux from the Rosebud Reservation, South Datota, who died in Washing-

ton after participating in the parade after President Woodrow Wilson's inauguration (pl. 18).

In the solemn ceremonies marking the burial of the Unknown Soldier of World War I in Arlington Cemetery on November 11, 1921, one man was selected to place a magnificent feather bonnet upon the casket as a tribute from all American Indians to their country's unknown dead. He was Plenty Coups, an aged, dignified war chief among the Crow Indians of Montana. This was one hundred years to the very month after the young Pawnee hero Petalesharro first appeared in the Nation's capital wearing a picturesque flowing-feather bonnet. During the intervening century the war-bonneted Plains Indian emerged as the widely recognized symbol of the North American Indian.

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2. Pagesgata, Republican Pawnee. Silhouette by Charles Willson Peale, 1806.

Early portraits of Plains Indians.

1. Lithograph in McKenney and Hall's *History of the Indian Tribes of North America*, 1836. After a portrait by Charles Bird King, 1821.

2. Detail from Samuel F. B. Morse's painting "The Old House of Representatives, 1822." (Courtesy Corcoran Gallery of Art.)

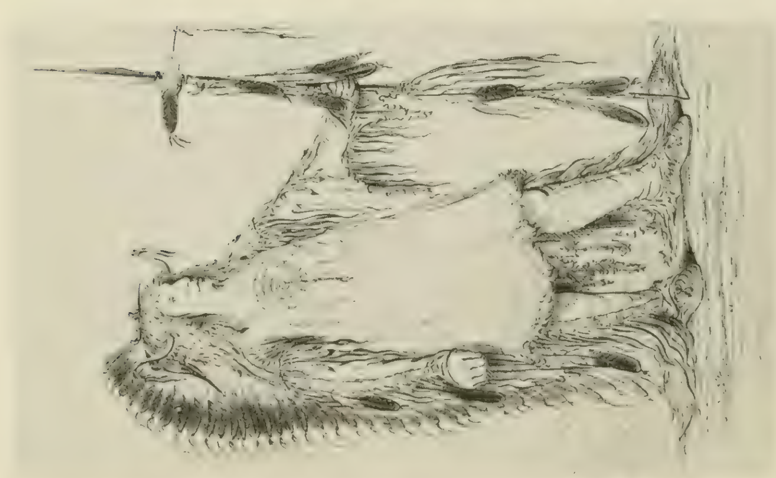
Petalesharro, popular Pawnee hero of 1821.

1. First published illustration of Plains Indian tipis, after Titian Peale's field sketch on Major Long's expedition to the Rocky Mountains of 1819–20. (1823)

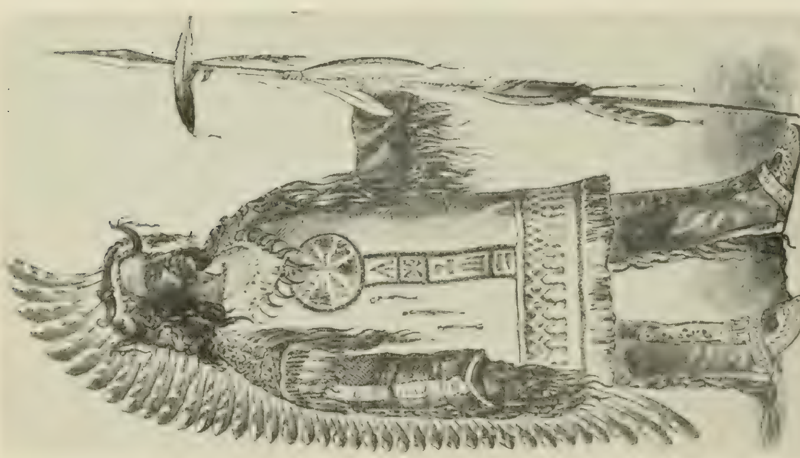
2. Ongpatonga (Big Elk), Omaha Head Chief. Lithograph after a painting by John Neagle in 1821. Frontispiece in Samuel Morton's *Crania Americana*, 1839.

Sioux Warrior Charging. Lithograph in *The American Turf Register and Sporting Magazine*, October 1829. A pioneer picture of Plains Indian life by Peter Rindisbacher.

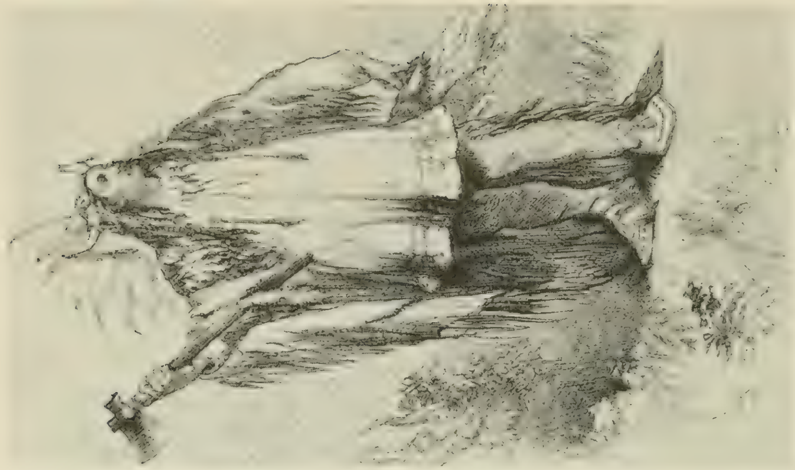
Hunting the Buffaloe. Lithograph in McKenney and Hall's *History of the Indian Tribes of North America*, 1836. A pioneer picture of Plains Indian life by Peter Rindisbacher.



1. Four Bears, Mandan second chief, by George Catlin, from his 1841 book.



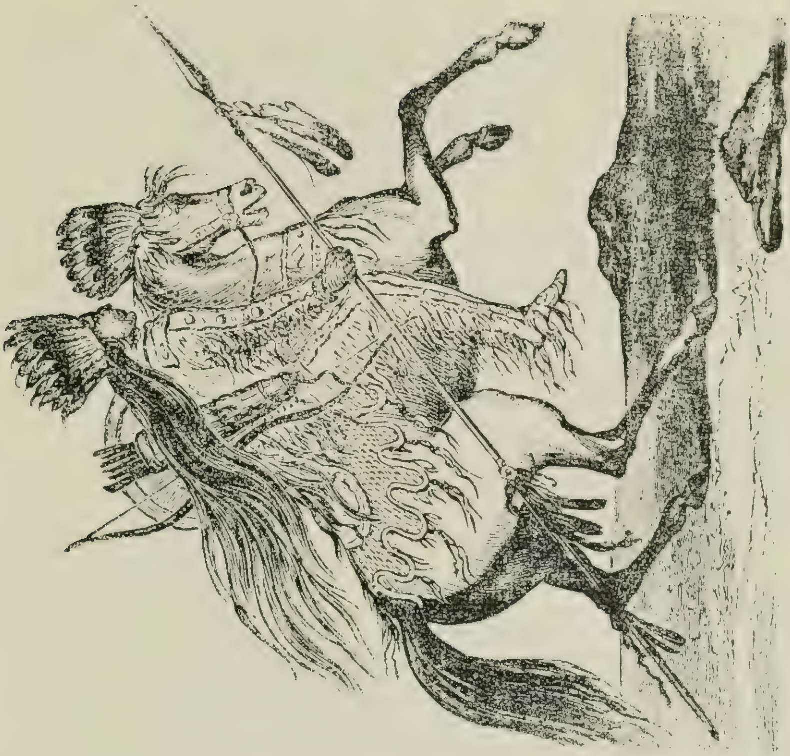
2. "Pontiac," from William V. Moore's *Indian Wars of the United States*, 1856.



3. "Paw-puk-keewis," from Longfellow's "Song of Hiawatha," 1856.

An example of George Catlin's influence upon illustrators.

1. "He-Who-Jumps-Over-Everyone," a Crow Indian, by George Catlin, from his 1841 book.



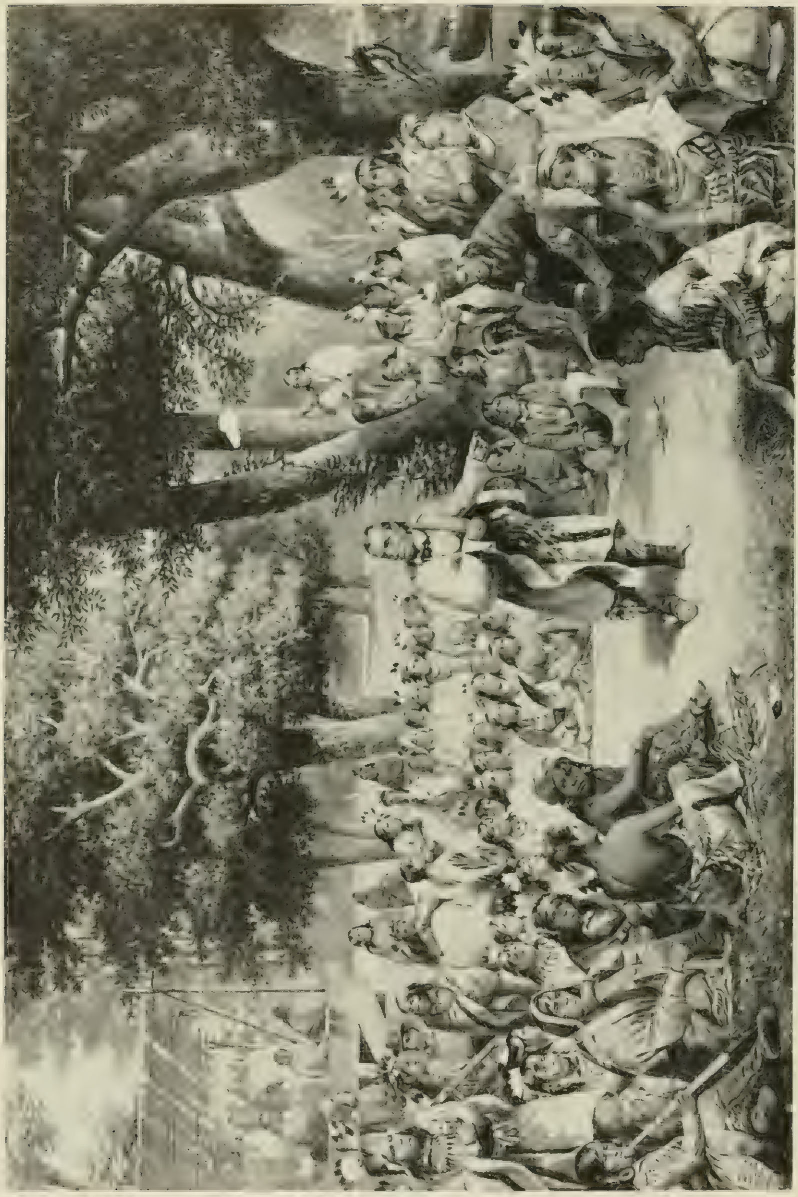
2. "A Creek Warrior," from William V. Moore's *Indian Wars of the United States*, 1856.

Another example of Catlin's influence upon illustrators.

INDIAN BUFFALO HUNT.

"Indian Buffalo Hunt," after George Catlin. This Indian scene by the famous illustrator Felix O. C. Darley is from John Frost's *The Book of Indians of North America*, 1852.

“Return from the Hunt,” an Indian scene by the famous illustrator Felix O. C. Darley. Lithograph, 1885.



John Mix Stanley's "The Trial of Red Jacket," painted in 1868.

"Indians Attacking Butterfield's Overland Dispatch Coach," from a field sketch by Theodore R. Davis. *Harper's Weekly*, April 21, 1866.

"Custer's Last Fight," lithograph by Otto Becker, 1896.

Poster advertising Buffalo Bill's Wild West Show, 1887. (Courtesy Buffalo Bill Historical Center, Cody, Wyo.)

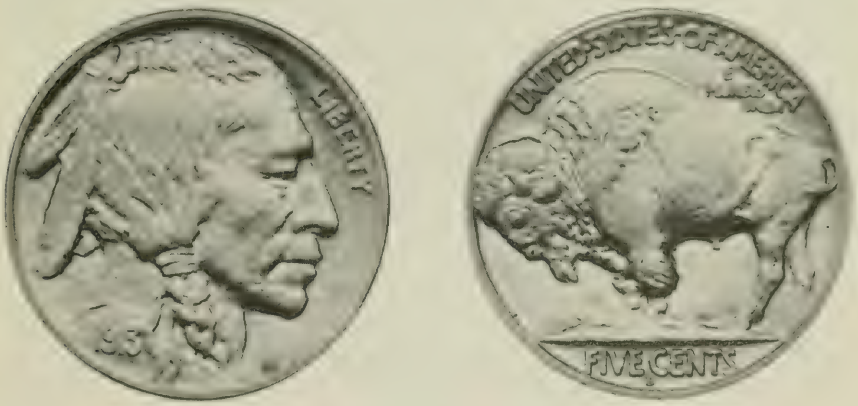
Cyrus Dallin's "The Medicine Man" in Fairmount Park, Philadelphia. (Courtesy Fairmount Park Art Association.)

1. Cayuse Indians of Oregon. Photograph by Major Lee Moorhouse, ca. 1900.

2. Cherokee Indian "chiefing" for a curio shop in Cherokee, N.C. Photograph by the author, 1962.

"The First Thanksgiving" by Jennie Brownscombe (ca. 1919), exhibited in Pilgrim Hall, Plymouth, Mass. (Courtesy of Pilgrim Hall, Plymouth, Mass.)

1. Iron Tail, Sioux, one of James Earle Fraser's models for the Indian side of the "buffalo nickel."



2. The "buffalo nickel," first minted in 1913.

Hollow Horn Bear, Sioux Indian model for the 14-cent "American Indian" stamp shown in the inset. The stamp was issued May 30, 1923.

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